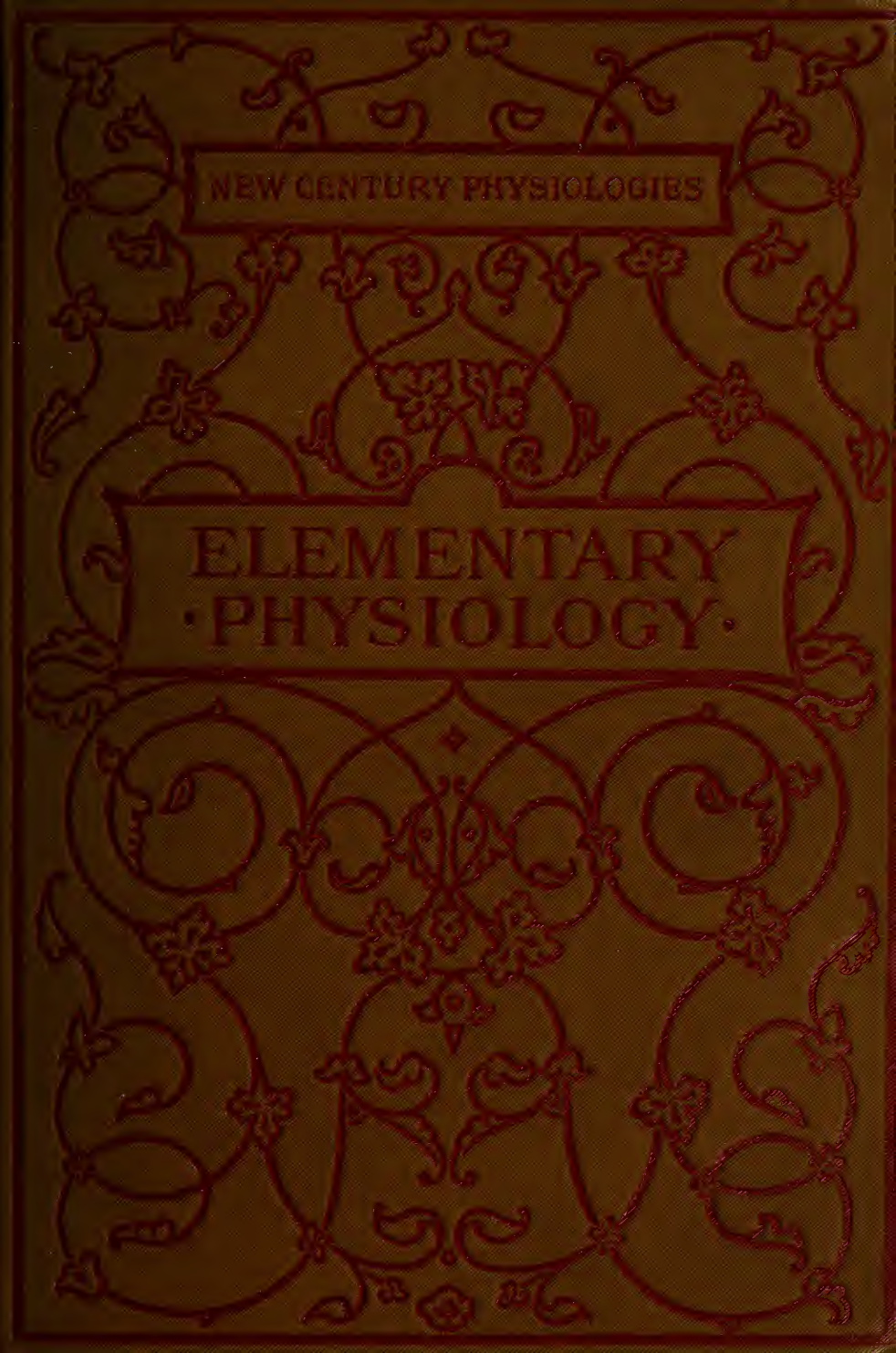


The entire cover is framed by an intricate, symmetrical floral and vine border. The design features scrolling vines, acanthus leaves, and small floral motifs, creating a classic, ornate appearance. The border is composed of multiple layers of these decorative elements, filling the space around the central text.

NEW CENTURY PHYSIOLOGIES

ELEMENTARY
· PHYSIOLOGY ·

LIBRARY OF CONGRESS.

QP 36
Chap. _____ Copyright No. _____

Shelf H 15

UNITED STATES OF AMERICA.



NEW CENTURY SERIES

OF

ANATOMY PHYSIOLOGY AND HYGIENE

BY

HENRY F. HEWES, A.B., M.D. (HARVARD)

Teacher in Physiological and Clinical Chemistry,
Harvard University Medical School, Boston.

WINFIELD S. HALL, PH.D., M.D. (LEIPSIC)

Professor of Physiology,
Northwestern University Medical School, Chicago.

NEW CENTURY SERIES

OF ANATOMY PHYSIOLOGY AND HYGIENE

1. ORAL LESSON BOOK IN HYGIENE.
For Primary Teachers.
2. THE NEW CENTURY PRIMER OF HYGIENE.
First Book for Pupils' Use
3. INTERMEDIATE PHYSIOLOGY AND HYGIENE.
For Fifth- and Sixth-Year Pupils, or Corresponding Classes in
Ungraded Schools.
4. ELEMENTARY ANATOMY PHYSIOLOGY AND HYGIENE.
For Higher Grammar Grades.
5. ANATOMY PHYSIOLOGY AND HYGIENE.
For High Schools.

NEW CENTURY SERIES
OF ANATOMY PHYSIOLOGY AND HYGIENE

ELEMENTARY ANATOMY PHYSIOLOGY AND HYGIENE

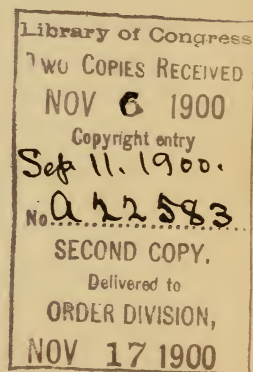
FOR

HIGHER GRAMMAR GRADES

BY

WINFIELD S. HALL, PH.D., M.D. (LEIPSIK)

PROFESSOR OF PHYSIOLOGY, NORTHWESTERN UNIVERSITY MEDICAL
SCHOOL, CHICAGO



NEW YORK ·· CINCINNATI ·· CHICAGO
AMERICAN BOOK COMPANY

INDORSEMENT

WE, the undersigned, have carefully examined the school text-book entitled

ELEMENTARY ANATOMY PHYSIOLOGY AND HYGIENE FOR
HIGHER GRAMMAR GRADES

by PROFESSOR WINFIELD S. HALL, M.D., with reference to the following points:

1. Fullness and accuracy of subject-matter relating to the nature and effects of alcoholic drinks and other narcotics upon the human system.
2. Amount of matter on general hygiene.
3. Presentation of matter with regard to its adaptability to the class of students for which it is designed.

We are satisfied that on all of these points, as well as in the regular anatomy and physiology, the treatment is as complete as is required for a book of this grade, and fully in harmony with the results of the latest investigations. We therefore heartily indorse the book for Higher Grammar grades or pupils.

A. H. PLUMB, D.D.
REV. JOSEPH COOK, LL.D.
DANIEL DORCHESTER, D.D.
WILLIAM A. MOWRY, PH.D.
L. D. MASON, M.D.
T. D. CROTHERS, M.D.
CHAS. H. SHEPARD, M.D.

*Text-book Committee of the Ad-
visory Board.*

MRS. MARY H. HUNT,
*World's and National Superin-
tendent of Scientific Temperance
Instruction for the Woman's
Christian Temperance Union.*

COPYRIGHT, 1900, BY
AMERICAN BOOK COMPANY.

HALL EL. PHYS.
W. P. I

PREFACE

No field of school instruction has in recent years undergone a more radical change in the method of presentation than that of the *natural sciences*. This change has been a progressive one, and each year has recorded some advance. In all nature work in the grades as well as in all natural science work in the secondary schools and colleges *the pupil is brought into contact with the material studied*. This is effected either through demonstrations before the class or through laboratory or field work in which the individual pupil, under the direction and inspiration of the teacher, observes or experiments with the material.

Physiology is a most important branch of the biological division of the natural sciences. Besides making a large part of both botany and zoölogy, it is set apart as a science by itself, devoted to the discussion of the functions of living matter. The nature work of the lower school grades leads naturally and logically to physiology, for which it forms a necessary basis.

The subject of human physiology is the most important part of the nature study of the schools. It introduces the pupil to the physical house in which he must abide while he lives in this world and, with hygiene, to the essential conditions of highest attainment.

With these principles in view, the subject of human physiology has been introduced with a brief treatment,

largely experimental and practical, of the physiology of a growing plant. Through this means one can best show the interdependence of plant and animal kingdoms, and the unity and harmony of nature.

Attention is called to the experiments suggested and described in the text. The appliances and material suggested are readily procurable; and the experiments described may easily be performed by any bright and energetic teacher. Taught in this way physiology becomes a living and intensely interesting science. The problems given for solution by the pupils will tend to fix indelibly the hygienic principles involved in them.

Especial attention is called to the lessons on *Domestic Economy*. This work has never failed to arouse the interest not only of the pupils, but of parents also, their feeling being that the school work in physiology is being made practical as life itself is and must be. This chapter and that on plant physiology is the work of Mrs. Winfield S. Hall.

The author is indebted to Professor Wilson of Columbia University, to Professor Piersol of the University of Pennsylvania, and to Professor Williams of the University of Buffalo for several valuable figures. Acknowledgment is due also to Messrs. Lea Brothers, Philadelphia, for permission to reproduce several figures from the author's *Text-book of Physiology*, of which they are the publishers.

WINFIELD S. HALL.

CHICAGO, June, 1900.

CONTENTS

GENERAL PHYSIOLOGY

CHAPTER	PAGE
I. Plant Physiology — How the Plant lives and grows	11
II. The Cells, Tissues, and Organs of the Body	27
III. The Nervous System — How the Different Organs are made to work in Harmony	46
IV. Narcotics — Their Nature, their Classes, and their Gen- eral Action upon the System	58

SPECIAL PHYSIOLOGY

V. Nutrition — How the Body is nourished	76
VI. Circulation — How the Nourishment is distributed	126
VII. Respiration — How the Blood is purified	164
VIII. How the Food is used in the Body	196
IX. How the Waste Materials are thrown out of the Body	206
X. The Skin — How it is made and what it does — how to take care of it	211
XI. The Special Senses — How one knows what is going on about him	225

CHAPTER	PAGE
XII. The Nervous System — The Brain, the Spinal Cord, and the Nerves	237
XIII. The Muscles — How the Body moves	251
XIV. The Skeleton — The Framework of the Body	263
INDEX	271

PHYSIOLOGY AND HYGIENE

PHYSIOLOGY is one of the *Natural Sciences*. It tells how plants and animals live. It tells just what each part of the living being does, and how all of the parts work together. For example, it tells how the stomach digests the food we eat; how the food is absorbed and distributed to all parts of the body by the heart and blood vessels, and how each part of the body is nourished by the food thus brought.

Hygiene tells how to take care of the body. Every one wishes to have a healthy body. There are many things that injure the body, and many other things that make the body grow large and strong and healthy. Hygiene tells first, what is proper for the body, and second, what will injure it, and what should therefore be avoided.

Physiology treats not only of man, but of all other animals, as well as of plants. Animals could not live upon the earth if the plants did not prepare food for them. One might think that man could live upon milk and eggs and meat if there were no plants to furnish vegetable food; but a second thought makes it plain that the animals which furnish us with milk, eggs, and meat live upon vegetable foods, such as grass and grain. Thus we are all dependent finally upon plants.

If one understands something of how plants live, that is, of *Plant Physiology*, it is much easier to understand *Animal Physiology* and *Human Physiology*. We shall

begin our study of physiology by the study of how a plant lives and grows; then we shall study how the cells and tissues, of which the human body is built, live and grow, and the part which they play in bodies. This part of the general science of physiology is called *General Physiology*.

GENERAL PHYSIOLOGY

CHAPTER I.—PLANT PHYSIOLOGY—HOW THE PLANT LIVES AND GROWS

1. THE PLANT AND ITS NEEDS

HERE is a kernel of corn that is dry and hard, and here is another which has been in water for a few days. Notice what a change has taken place in those few days. The little dried-up kernel has become large, full, and soft.

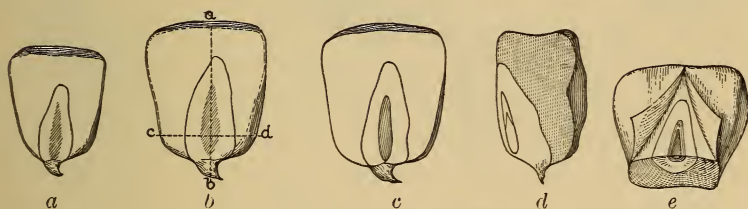


FIG. 1.—*a*, a dry kernel of corn. *b*, a soaked kernel. *c*, soaked kernel from which a thin slice has been cut. *d*, soaked kernel cut through along the line *ab*, (*b*). *e*, soaked kernel cut through along the line *cd*, (*b*). The skin of the kernel is peeled up and one can see the plantlet lying in its little bed of food.

Inside the change is still greater. If one opens a dry kernel, he will see in the midst of the white part a softer, yellow part which, in the soaked kernel, has become much larger and is plainly a little plant (Fig. 1).

Here is still another seed that has been in the wet earth in a warm place for five or six days, and in this we see the

perfect little plant partly within and partly without the kernel (Fig. 2, *a*). What suddenly started this little plant to growing after lying asleep all winter? What waked it up?

It could not have been the water alone, for the kernels which were put in damp soil or water and set in a cold place showed no sign of life. Nor could it have been



FIG. 2.—The corn plant growing from the kernel. *a* shows the size of the plant at one week, *b* shows the size at ten days, and *c* at two weeks.

heat alone, for those that were put in a warm window without water still slept on. But when we gave them both heat and moisture, they awoke and began to grow. The growth, however, would soon stop if the plant had no food, so nature has put the food where the plant can get it most easily.

The white part and the yellow part of the kernel are all the food which the plant needs until it is old enough and strong enough to earn its own living. But even with all the moisture and heat and food which it needs, a plant cannot be healthy without one thing more.

You have seen a potato growing in a dark cellar, and have noticed its sickly, yellow color and long, weak shoots; perhaps, too, you have seen a spot on the grass where a board has lain for several days and which when removed showed the grass with yellow blades instead of green ones.

Without light there could be no green color in the leaves nor strength and vigor in the plant; without food the plant could not grow, and after living for a time upon its own tissue, it would die; without moisture the plant would wither and dry up; without warmth, the light, food, and moisture could not do their work.

After the plant has started to grow, it grows in two directions, one part pointing up and becoming the stem, and the other pointing down and becoming the root, and whichever way the seed is planted, the stem will turn upward even if it has to make a complete turn to get started in the right direction.

If we look at the seed after the plant has been growing for two weeks, we shall find there is little of the seed left within the shell, for the plant has eaten all the stored-up food (Fig. 2, *c*).

2. THE PLANT AND ITS NEEDS (*continued*)

WE have seen that a plant needs food and drink, heat and light, but we have said nothing about another need that is quite as great; that is, the need of the oxygen of the air.

A plant not only eats and drinks, but it breathes. All plants breathe oxygen by day and by night. In plants that have leaves, the leaf is the organ of breathing; in other plants the breathing is done by means of the body of the plant.

Before we can understand the use of the oxygen we must know something further of the food and the work of the plant. A plant cannot eat solid food. It must take its food either as a liquid or as a gas. The liquid food is taken from the earth through the roots, and the gases are taken from the air through the leaves. At least half of the solid part of a plant body is carbon, and the plant must have a continuous supply of carbon to satisfy this need.

There are several forms of solid carbon, such as coal or plumbago, but plants cannot eat solid foods, so that these forms cannot be used. The plant must take carbon in the form of gas, and this gas is called carbon dioxide. The plant can absorb this through the leaves and use it as a food. The most important food of a plant is carbon dioxide, which is absorbed from the air by the leaves.

Carbon dioxide is composed of carbon and oxygen. Carbon when alone is a solid like coal, or coke, or plumbago. Oxygen when alone is a gas. The air is composed of a mixture of gases, of which oxygen comprises about one fifth of the whole amount. When oxygen and carbon are joined together they make a gas which is called carbon dioxide gas. Carbon dioxide forms a very small part of the air. The leaves absorb the carbon dioxide, and if the plant is in the sunlight, the green coloring matter in the leaf separates the carbon from the oxygen. The carbon remains in the plant as a part of the plant, while the oxygen escapes from the leaves as a gas. All of this wonderful process is a part of the plant's eating.

To understand the way in which a plant breathes, we must study the subject of oxidation. Have you noticed that a fire which has been given plenty of coal will stop burning if we close the draught? If the draught is not perfectly closed, the fire will burn slowly; but if quite closed, the fire will go out. It is plain that the fire needed something which it did not get. It had no oxygen. The coal cannot burn without the help of oxygen. This burning we call *Oxidation*.

You have seen copper become tarnished and iron become rusted when exposed to the air. In both cases they have become oxidized. When the coal became oxidized, it was a quick process which we call rapid oxidation, but when the iron became oxidized it was by slow oxidation.

Oxidation always produces heat. Rapid oxidation takes place in a short time with a great heat, while slow oxidation gives little heat during a long time.

Heat may be used for warming houses, for cooking, or for producing power to move machinery.

In the plant oxidation is used principally for power to do the work of the plant. The plant work is to push itself upward and to carry food from the ground to the highest point, and later to form the seed. It is the union of carbon and oxygen that gives the plant power to grow and to feed itself, and to make a new plant.

As the leaf is the organ for inhaling, it is also the organ for exhaling. This is done by means of the cells in the surface of the leaves. Let us remember, then, that every plant has work to do; that to get the power to do this work it must oxidize its own substance with the oxygen of the air. Remember that oxidation of the substance of a living plant or animal is *breathing*. All living things breathe in oxygen, which combines with the carbon and

other substances to form carbon dioxide and other combinations, such as water. After the carbon dioxide is formed it is always thrown out of the animal body, but the plant leaves can use it for food when the sun shines.

3. THE PARTS OF A PLANT

WE found the first need of a plant to be warmth and moisture, and found, too, that for days the plant could live upon nothing more than the food in the seed, with the water which it took in through the roots and the oxygen absorbed by the leaves from the air.

We can easily understand from this that a large part of a young plant and some part of all plants is fluid.

The fluid is in every part of the plant, and when it is mixed with the food it becomes the sap. If you have tasted maple sap, you will remember that it was not like water, but was thicker and tasted sweet. That is because it has taken up the food of the plant, which it must carry to every part.

Besides the liquid part the plant has another part, and this part we call the tissue, just as we call the substance of your dress or coat, the material, the fabric, or the tissue. As the tissues have different uses, we call them by different names. Those that are active and do the work of the plant, we call *active tissues*; those that support the active tissues we call *supporting tissues*, and those that cover and protect we call *protecting tissues*. Let us see if by thinking a little we can find which tissues belong to each division.

We know that the work of this plant is done by the leaves, the root, and the stem.

In all of these organs we find the living substance of

the plant, which is called *protoplasm*. In the leaves it is green protoplasm, and in the stem and roots it is white protoplasm. All of the active tissues of the plant contain protoplasm, and are in the leaves, in the stem, and in the root. Most of the leaf is active tissue, but only a small portion of the stem and root is active tissue. The delicate root hairs contain protoplasm and represent active tissue.

If you hold a leaf up and look through it toward the light, you will see the branching veins of the leaf. These veins serve a double purpose in the leaf; (1) they support the active tissue of the leaf; (2) they serve as a circulatory system along which the sap of the plant flows. The stem is made up almost wholly of supporting tissue, the only active tissue being the inner bark in the case of trees and shrubs. What is true of a stem of a tree is also true of a root.

Protecting tissue is found upon every plant. The delicate, transparent skin which covers the little corn plant is its protecting tissue. The thick bark which covers the trunk and branches of trees and shrubs is their protecting tissue. Seeds have protecting tissue. The transparent skin so easily peeled off from a soaked kernel of corn is its protecting tissue. A nut has a hard, woody shell outside and a delicate brown skin inside, to protect it as it lies upon the ground all winter, waiting for the warm spring sunshine to wake it up.

4. THE PLANT ORGANS

THE tissues are but the materials of which the working part of the plants is made, and these working parts we call *Organs*.

We have already spoken of the leaf as the organ of breathing. On its surface both above and below are cells through which the oxygen passes. The leaf is formed of the three kinds of tissue. Inside is the living part or protoplasm, kept in place by the supporting tissues, the veins, and the whole leaf covered by the protecting tissue or skin.

The work of feeding is shared by two organs, the leaf which gets the gaseous food from the air, and the root, which gets the liquid food from the ground. This organ is composed of all three tissues. In large plants the main part of the root is supporting tissue, whose work is to hold it upright and firmly fixed in the ground; but each large branch of the root has a thin coat of active tissue under its bark. In small plants like the little corn plant, the main part of the root is active tissue, composed of fine rootlets and root hairs, all filled with protoplasm and sap, and held in form and made strong by the cellulose, and covered and protected by the skin.

The stem with its branches is the organ of form, and gives to the plant its shape. Without this part the plant could not grow tall, nor send out arms, nor have any of the beautiful forms which plants now take. It would lie flat and formless.

The little corn plant which we have been studying has no other organs than the root, stem, and leaf, but in a mature plant there is still another organ, the flower, to which is given the highest work of the plant. The flower often adds beauty, color, and fragrance, but these things are not its real work. Its work is the making of a new plant of the same kind as the parent plant, and this is the crowning work of the whole plant. During the entire summer the leaves breathe in oxygen, the roots

take in food, the veins carry it all over the plant body, all to give the plant strength to form the seed, which holds the sleeping plant for the following year. This work of making the seed and storing up within it the food for the young plant is so hard that it requires the help of the whole plant. But, as upon the seed depends the future good of the plant family, so each plant gives its work for the family good.

It is so important that the plant prepare this seed and ripen it that if it cannot get the proper food and drink for growth and seed making, instead of using what it does get for its own growth, it sacrifices its growth and hastens to form the flower, which in turn will produce the seed and insure the next year's plant.

5. THE SEED AND WHAT IT CONTAINS

WE have talked about the young plant and its needs; the growing plant and its needs; the material from which the plant is made; and the organs of the plant and their work. The most important organ we found to be the flower, and its most important work the making of the seed. Now we will talk about the seed and its material. Let us look first at the outside. Here is a seed that has been in water for three or four days (Fig. 1, page 11). If you use a penknife or a pin, you can loosen the outside part or skin. Look at it and see how tough it is. When it was on the kernel, it looked yellow, but when it is taken off, it looks colorless, and we now know that the color showed through and that the skin itself is transparent. Did you notice where the skin stopped? If you look carefully enough, you will see that the point of the seed is not covered. This is where the kernel is fastened to the

cob. The skin is entire over the seed except over this point.

Now we have taken off the skin and can see the body of the kernel. Look at the soaked kernel in which the parts have become swollen and are more easily seen. Now the little plant or *germ* can be loosened from the other part which is the plant food. In this seed that has been in the warm earth for five or six days the parts of the germ can be seen : the point which grows upward called the *plumule*, and the point which grows down called the *radicle*. Notice that what was a groove in the dry seed has filled out in this soaked seed, and in the seed that has been growing for a week we can see the root growing downward from the pointed end of the seed, and the plumule growing upward from the middle of the side of the kernel in which the germ lay. Notice that on one side of the kernel there is a little bed of soft yellowish substance, in the midst of which the germ lies. This soft yellowish substance forms the first food of the little plant when it wakes up or sprouts in the spring.

It will be interesting to find of what the seed and the germ are composed.

The germ itself is composed largely of protoplasm within thin cellulose walls and covered with a thin skin. Around this tender germ is a layer that is nearly all protoplasm or proteid, and around that layer is the main part of the seed, which is starch. On each side of the kernel is a yellow part which contains the oil mixed with starch, and besides these materials are some minerals, such as salt and lime.

EXPERIMENTS

Get five cents' worth of iodine from the drug store. Dilute a part of this with water to a light brown color. Make a thin paste of laundry starch boiled with water.

1. Put some of this paste in a drinking glass. Pour into the starch a little of the dilute iodine, and notice that the starch instantly turns to a beautiful blue color. This is called the *iodine test for starch*.

2. Put a little piece of lean meat in some of the strong iodine and notice that the meat turns brown. This is the *iodine test for proteid* (see page 85).

3. Cut some thin slices across a soaked grain of corn ; put them into any little shallow dish like a watch crystal or a butter dish, and notice that the white part of the kernel turns blue, showing the presence of starch ; and that the yellow part around the germ turns brown, showing the presence of proteid there. The germ itself turns brown because its protoplasm is one kind of proteid.

4. Remember that the kernel contains the first food of the plant ; that this food is composed of starch, of proteid, and of oil ; that iodine turns starch blue and proteid brown.

6. PLANT DIGESTION

WE know that as plants eat they must have food, and that it must be in a form in which the plants can use it. As they can take no solid food, they must take all of their nourishment in the form either of gas or of liquid, and as many foods are not soluble in water, there must be some other process which changes them to a liquid form. This change is called *digestion*.

Plant digestion is of two kinds, the *digestion of the seed food*, which takes place within the seed when the germ first wakes up and is feeding upon the food stored for it by the parent plant ; and the *digestion of the soil food*, which the roots take up from the ground.

It often happens that both kinds of digestion are going on at the same time ; for example, when the wakened germ is living mainly upon the seed food, but has sent out one or two roots which bring in new material from the ground. As the roots can take only liquid food and the leaves only gaseous food, all changes in the food — or digestion — must take place outside of the plant body. Therefore the plant has and needs no digestive organs, but it does have digestive fluids, which it sends out to dissolve mineral matter or to change it into a liquid that can be taken up.

We found a large part of the kernel of corn to be starch ; but if you were to examine the plant itself, you would find no starch at all, and yet the germ plant lives upon that stored-up starch. It is evident then that some change must have taken place in the food.

The foods that are found in seeds are either sugar, starch, oil, proteid, or cellulose, and all of these excepting the sugar must be digested before they can be used by the growing germ, and must be digested by some *ferment*.

Do you know what is meant by a ferment ? If you put corn or beans to soak in water for several days, you will find that the water becomes cloudy and has tiny bubbles on top ; that shows the work of a ferment. The same ferment will not digest all the kinds of food which seeds contain, but it requires one kind of ferment for oil, one kind for proteid, and another for starch and cellulose.

Knowing that the food cannot be digested without a

ferment, we naturally want to know where this ferment comes from and what it does.

Let us go back to our first lessons, and we shall find that the plant germ sleeps in the seed until it is wakened by the action of the heat and moisture working together. If the germ has only water or only heat, it sleeps on, but when it has both in the right amount, it awakens.

Bears and some other animals sleep during the winter in some warmly covered, dark place, neither eating nor drinking, and breathing but slightly. In the spring they awaken and are so hungry that when we wish to express great hunger we say "as hungry as a bear."

The germ within the seed also sleeps during the winter and awakens in the spring "as hungry as a bear." The mother plant had prepared for this hunger, and right at hand the awakening germ finds food. When the protoplasm is awakened, it forms a ferment out of its own substance, and this ferment digests the different foods. One kind of ferment digests the starch and cellulose, another kind digests the oils, and still another the proteid matter. After the food has been acted upon by the ferment it is ready for the plant to use in building up new parts.

All the seed foods are digested in this way; but when the plant becomes old enough and strong enough to put out roots and to produce root hairs, then the plant uses another kind of digestion. The young plant carries on first the ferment digestion and then both kinds of digestion at once until the seed food is all used up.

From the soil the plant takes up mineral food, of which it could get very little from the seed.

A plant must have mineral matter to make it strong enough to stand upright.

The minerals of the soil are solid, and are not soluble

in water. If they were, the rains would wash them away, as they have washed the soluble salt, into the sea.

Before minerals can be used as plant food they must be dissolved, and water will not do it. A way has been provided by means of the root hairs. These root hairs make an acid which dissolves the grains of mineral matter which are held close to the root by the close-growing root hairs. As soon as the mineral is dissolved it is taken up by the root hairs, forms a part of the sap, and thence is carried all over the plant, where it is built up into the growing tissues, giving it that firmness which only mineral food can give. Some of the minerals used are quite common to us, as the lime and salt, but others quite as useful to the plant are not so well known to us. Some plants require more of one mineral, and others more of another kind, and this is one reason why different plants require different soils, and why it is better not to grow one kind of grain on a field year after year, but to change each year, thus having "a rotation of crops."

REVIEW OF PLANT PHYSIOLOGY

THE PLANT NEEDS:

Water

Heat

Light

Food { Liquid
Gaseous, Carbon dioxide

Oxygen

THE PLANT SUBSTANCE:

			{ Of leaves
			{ Of stem
			{ Of roots
			{ Of root hairs
<i>Tissues:</i> {	Active:	Protoplasm	
	Supporting	{ Veins Cellulose	
	Protecting:	Skin	

Fluid: Sap

THE PLANT ORGANS :

Leaf — organ for breathing and eating gas.

Stem — organ for form.

Root — organ for eating.

Flower — organ for producing a new plant.

THE SEED	{	<i>Skin</i>	
		<i>Germ</i>	{ Plumule Radicle
	{	<i>Food</i>	Sugar
			Starch
			Oil
			Proteid
			Cellulose

THE PLANT DIGESTION :

Of Seed Food :

Sugar	{	Digested by ferments secreted by plant germ.
Starch		
Cellulose		
Proteid		
Oil		

Of Soil Foods : Mineral matter digested by and absorbed by the root hairs.

THE PLANT ECONOMY :

In Food stored for future use :

Root	{	Underground
Stem		
Seed		
		Aerial

In Sleep during the Winter :

Germ plant sleeps in seed.

Adult plant sleeps.

In eating Carbon dioxide.

In breathing oxygen, to get the energy which the plant needs to do its work.

In changing mineral matter to vegetable tissue which is built up into the plant.

THE RELATION OF PLANTS TO ANIMALS

Plants can digest minerals and change them to a form which the animal may use.

Plants can eat carbon dioxide and water, and from these two substances can make sugar, starch, and oil, all of which are used by animals for food.

Carbon dioxide is harmful to animals. As the plants consume it they make the atmosphere more healthful for the animals. Thus animals owe a great debt to the plants.

Plants could not do these wonderful things if it were not for the sunshine. Thus we see that all nature is bound together into one great harmonious whole.

CHAPTER II. — THE CELLS, TISSUES AND ORGANS OF THE BODY

1. THE GENERAL STRUCTURE OF THE BODY

IN our study of the plant we found that its body is composed of organs; namely, the root, stem, leaves, and flowers. We found that each one of these parts of the plant body did a special part of the work which the plant has to do.

In a similar way the body of every animal is composed of organs, and each organ has a particular work to do. The stomach is an organ whose work is to digest food; the heart is an organ whose work is to pump the blood through the arteries and veins to the various parts of the body. The skin is an organ whose principal work is to protect the sensitive organs which it covers.

The skin is a coat which the body always wears. In our cool and changeable climate the skin does not furnish enough protection, so that animals are furnished by Mother Nature with thick, warm coats of fur. But man is endowed with higher faculties than are the lower animals and, left upon his own resources, he makes for himself a thick, warm garment. He uses various materials, weaves them into fabrics, and then combines the fabrics into a garment. This garment, which we will suppose is a coat, is an organ, perfectly adapted to do a special kind of service for the man.

Let us study this artificial organ, this coat, to see how it is constructed. It has a thicker outside and a thinner

lining. It may also have a middle layer to make it warmer ; that is, better adapted for its work. These layers of which the coat is composed are of fabrics ; that is, they are tissues. Any piece of cloth is a fabric or tissue. But how are these fabrics constructed ? If you examine a piece of cloth, you will find that it is made of threads woven together. If you examine a thread, you will find that it is composed of fibers. So that this artificial organ, a man's coat, is composed of fabrics or tissues ; the tissues are composed of fibers or bundles of fibers.

In a similar way organs of the body are composed of various layers of tissues, and these in turn are composed of fibers, and bundles of fibers woven together. Some tissues are composed not of a woven layer of fibers, but of tiny globular, cylindrical, or rectangular bodies set side by side like the bricks or blocks in a pavement. These little bodies are called cells.

So we may remember that the body is composed of organs, the organs are composed of tissues, and the tissues are composed of fibers or cells.

2. THE CELL—WHAT IT IS AND WHAT IT DOES

IF one looks very closely at a slice of watermelon, he will be able to see that it is composed of tiny spherical globules lying side by side. They are almost too small to see without the help of a magnifying glass, and yet there are few plants which have larger cells, and most plants have smaller ones, too small, in fact, to be seen without a magnifying glass or a large microscope.

The compound microscope was invented by a Hollander about three hundred years ago, but little practical use was made of it until a century later, when it began to be used

for the study of plant and animal tissues. It was very soon discovered that plant tissues are composed of little chambers which are spherical, cylindrical, cubical, prismatic, spindle-shaped, or irregular in form. The early workers with the microscope chose the name *cell* for these little chambers. When it was discovered that the cells

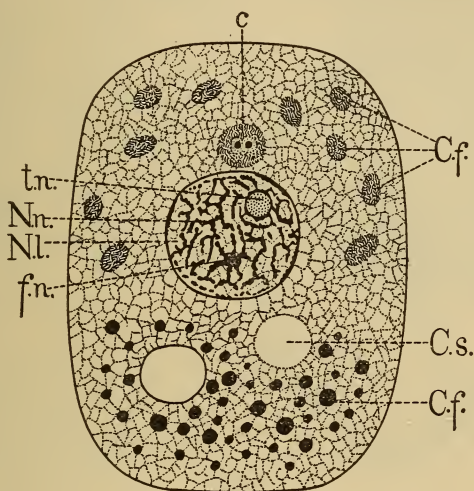


FIG. 3.—Diagram of a cell. [After Wilson.] Notice in this diagram of a typical cell the cell protoplasm, composed of cell plasm and cell lymph, and containing cell foods (*C.f.*) and cell sap (*C.s.*). The large spherical nucleus has a true nucleolus (*t.n.*), a false nucleolus (*f.n.*), a nuclear network (*N.n.*), and nuclear lymph (*N.l.*). *c* is the centrosome.

were usually filled with a liquid, it was not known how important this liquid is.

It was found out later that the liquid inside the little chambers is alive and is of far more consequence than the house in which it lives. The living substance is called *protoplasm*. Each little globule of protoplasm builds a wall around itself. At first this wall was called a cell.

Now we use the word *cell* for the *globule of living protoplasm together with its wall*.

Protoplasm is not a clear liquid like water, but is composed of a network whose meshes are filled with a clear watery fluid which is called *cell lymph*. The network is composed of threads or strands of a grayish, sticky substance called *cell plasm*. The cell plasm is filled with minute grains. If the

reader makes a careful study of Figure 3, he will find all of the parts mentioned above; and in addition to these he will find the spherical *nucleus* in the middle of the cell. The nucleus has a wall, a network whose meshes are filled with lymph, and holds two small spherical bodies, the true and the false *nucleoli*.

If the reader now studies Figure 4, he will see practically

the same parts in a different combination. This cell is a plant cell, and the cell sap is much more abundant in proportion to the protoplasm than is the case in the animal cell. All plant cells have walls. Sometimes the walls of a plant cell are very thick.

Animal cells differ from plant cells in two very impor-

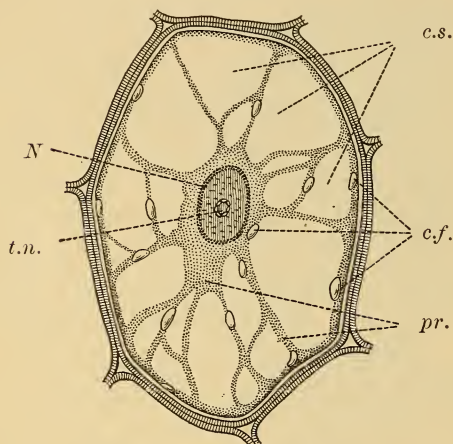


FIG. 4. — A typical plant cell. [Bastin.]

Pr. shows the protoplasm, with its granules, but the network is not shown. The cell sap (*c.s.*) occupies a very large part of the cell. The cell food (*c.f.*) makes a prominent addition to the figures. *N*, the nucleus, contains the true nucleus (*t.n.*). This cell had seven boundary cells.

tant ways: (1) they have a very thin membranous wall or perhaps no wall at all; (2) they have one or two small collections of cell sap, or more frequently no sap at all. Study Figures 5 and 6 and compare them carefully with

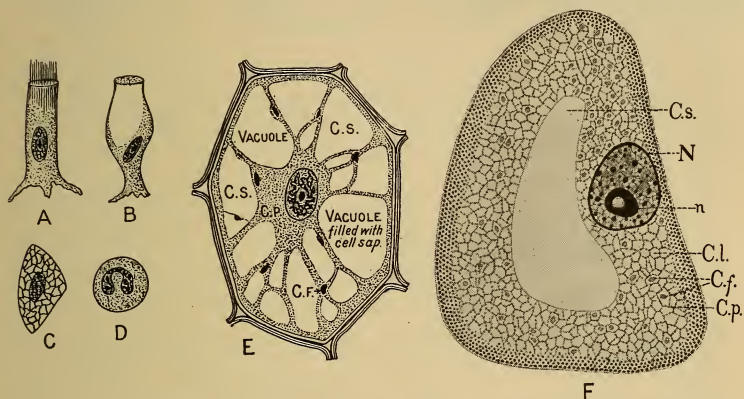


FIG. 5. — Typical cells of animals and plants.

- A. A cell such as found in the lining of the windpipe. The little hairs on the top keep moving quickly in one direction and slowly in the other, and thus carry dust and mucus up to the throat from the lungs.
- B. A cell from the windpipe, or nose, or intestine. This kind of cell is called a goblet cell. It is full of clear mucus. From time to time the cell empties out its mucus.
- C. A cell from the stomach. This kind of a cell helps the stomach to digest the food. Its part of the work is to help make the gastric juice.
- D. One of the blood cells.
- E. A plant cell. Notice: the numerous vacuoles filled with cell sap (*C.s.*); the cell protoplasm (*C.p.*) filled with innumerable tiny granules; the little masses of cell food (*C.f.*); the large nucleus with its nucleoli and network. The cell has a heavy wall, and one can see where seven other cells join it.
- F. A typical animal cell [Wilson]. *C.p.*, cell plasm; *C.l.*, cell lymph; *C.f.*, cell food; *C.s.*, cell sap; *N.*, nucleus; *n.*, nucleolus.

Figures 3 and 4. Remember that *the important part of a cell is the living protoplasm*, and that the protoplasm is composed of a network of *cell plasm*, whose meshes are filled with *cell lymph*; that the cell contains the *nucleus*, which has a network and nuclear lymph and contains one,

two, or three *nucleoli*; that there may be little masses of cell food; and small globules of cell sap; and, finally, that the plant cell nearly always has a thick cell wall while the animal cell usually has a very delicate membranous wall.

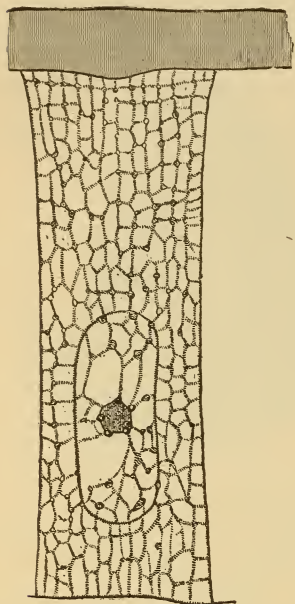


FIG. 6. — A typical animal cell. Notice that in this cell all the parts except the cell sap may be found. [Verworn.]

3. THE CELL, AND WHAT IT DOES (*continued*).

FROM the preceding lesson we have learned something about the parts of a cell. It seems wonderful that all these parts can be found within an object too small to be seen without a microscope. When we learn of the work which the cell is doing and the part which it plays in the world, it will all seem like a fairy story, but all of the facts to be given here have been observed many times by men who devote their lives to the study of these problems.

Every one has noticed the green powder which collects upon the tree trunks, fence posts, and stones or bricks which are in damp places out of doors. If one were to put a few grains of this green dust in a drop of water upon a glass and look at it with a strong microscope, he would find each grain to be spherical in shape, to have a transparent cell wall, and to be filled with a grayish mass in which may be seen many tiny green granules. These little spherical bodies are cells. Each one is a complete

plant (Fig. 7). Its green granules are the same as those which make the corn, wheat, grass, and trees green in



FIG. 7. — *Protococcus*, a dustlike, one-celled green plant, seen as a powder upon the trunks of trees, upon fences, stones, etc. In *b*, *c*, and *d* is shown the way in which the mother cell divides up into two, three, or more daughter cells. After division the cells may remain together in a colony, as in *b* or *c*, or they may separate, as shown in *d*.

color. If one examines under a microscope a drop of water from a pool or pond that has been standing stagnant for several weeks during the summer, he is sure to find little green bodies similar to the ones we have just studied. These are cells also. Some of them have little moving hairs whose whiplike motions propel the cells through the water (Fig. 8).

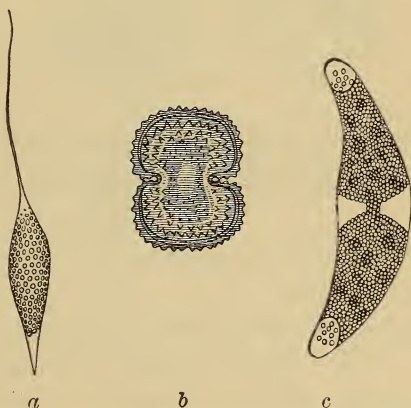


FIG. 8. — One-celled water plants. One of them (*a*) has a little whiplike tail whose rapid movements propel the plant through the water something like the swimming of a tadpole. But they are so small that hundreds of them would have plenty of room in a drop of water. *b* and *c* are *Desmids*, chiefly noticeable for their beauty.

Each of these one-celled plants leads an independent life. Each receives the light and warmth of the sun in its green granules. Each eats carbon dioxide gas and water; each makes sugar, and starch, and protoplasm. Each begins as a

very small cell and grows larger and larger until it becomes a grown up or adult cell. Each one raises a family of daughter cells, as they are called. Finally each one gets old and dies.

If one examines under a microscope a drop of water which he has taken, with a glass tube, from the slimy bottom of a stagnant pool, he is likely to see little globular or irregular grayish bodies, which keep changing

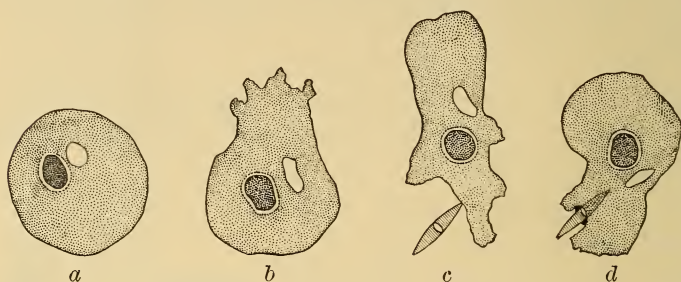


FIG. 9.—An *Amœba*. *a* shows the animal in a resting stage or asleep. *b* shows it as it starts out for something to eat. *c* and *d* show it coming in contact with a diatome and swallowing it through a mouth made for the occasion.

shape and creeping across the glass on which the water lies. These curious objects are living creatures which belong to the animal kingdom.

These little animals are called *Amœbæ*. When an amœba sleeps or rests, or when it is afraid, it draws up into a ball (Fig. 9, *a*). When an amœba gets hungry, it projects feet right out of its side anywhere. With these false feet, as they are called, it creeps over the surface on which it rests until it comes to some object which it can eat, when it opens a mouth anywhere and takes the object in. The figure (Fig. 9, *d*) shows the amœba in the act of swallowing a little one-celled plant. The amœba grows larger as it grows older. After a

while it becomes an adult mother amœba; then it divides into two daughter amœbæ. This process of raising a family is shown in Figure 10.

Mention has already been made of the movements made by the plant (Fig. 8) and by the hungry amœba. If one breaks off a slimy spray of a fine water plant and looks at

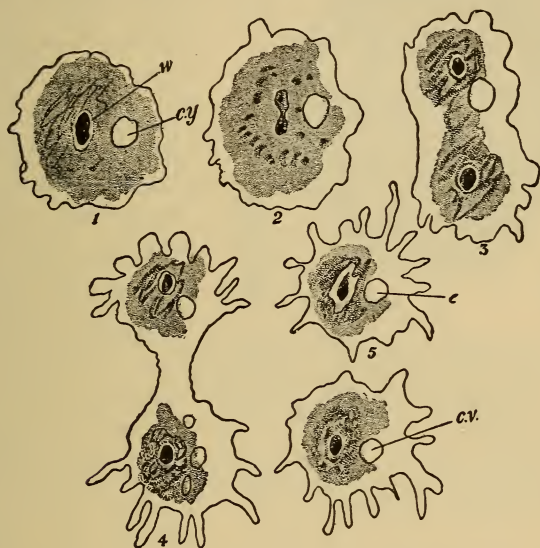


FIG. 10. — An adult amœba dividing into two daughter amœbæ. Notice that each daughter has a share of the parent nucleus, as well as a share of the parent protoplasm. [Hall.]

it under a microscope, he is likely to find some interesting little animals like those shown in Figure 11. The most noticeable feature of these one-celled animals is that when everything is quiet they extend the stem to its full length and open their bells as wide as possible. Each of these animals has a row of hairlike arms or tentacles called cilia around the bell. When anything disturbs, startles, or irritates them, they instantly fold the bells in, draw the

cilia together, and contract the stem until they occupy the smallest possible space. This all shows that they are *sensitive*, and that they can respond to a *stimulus*.

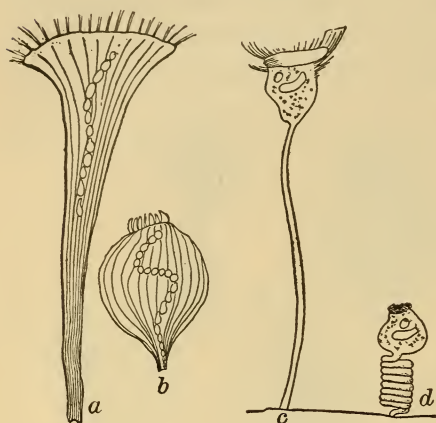


FIG. 11.—A *Stentor* (a, b) and a *Vorticella* (c, d). a and c show these little one-celled animals relaxed, with the bell open, and the little hairs around the mouth of the bell waving the particles of food into the open mouth of the bell. b and c show both animals contracted after something has startled them. [Verworn.]

Remember that all cells begin as small young cells and grow up to adult life by eating; that all cells have to work for their living; that all cells breathe in oxygen and breathe out carbon dioxide gas; that all cells are sensitive to things or conditions outside of themselves; and that many cells have the power of motion.

Remember that many plants and animals consist of only one cell.

4. TISSUES—HOW THEY ARE MADE AND WHAT THEY DO

If you will turn back to Figure 7 and Figure 10, you will see that full-grown plant cells and full-grown animal cells divide into two or more young cells which begin life as small, restless, hungry cells which forage for food, eat ravenously, and grow rapidly into adult cells. In the amoeba the daughter cells separate, and each one goes off by itself where it must fight its own battles single handed.

There are many little water animals larger and stronger than the amœba, which hunt for it, and when they find it devour it as a tender and nourishing morsel. The little green plant, *Protococcus*, shows us something new. Notice that in *b* and *c* (Fig. 7) the daughter cells do not separate, as do those in *d*, but remain together in a little family or colony. Figure 12 shows a plant of a higher order than the protococcus. It is placed

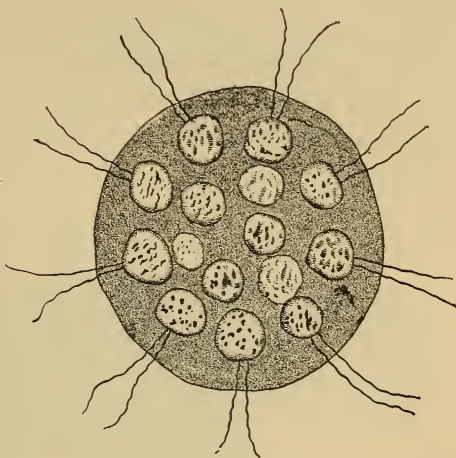


FIG. 12.—A little water plant composed of a colony of cells held together by a mass of gelatinous substance. [Verworn.]

in a higher rank because it is better fitted for the varying conditions of life. How is it better fitted? Just as a colony of men is better fitted than one person to meet the dangers of a pioneer life, so is a colony of cells better fitted to meet the dangers which exist in the pond or on the tree trunk. In union is strength. The enemy strong enough to overcome an individual easily does not dare to attack a colony, and thus the dangers are lessened. There is another great advantage in colonial life. Notice that both the colonial animal and the colonial plant have two kinds of cells. The outer cells of the little plant in Figure 12 are provided with delicate whiplike arms. With these arms the outer cells move the whole colony through the water or along the bottom of the pond or aquarium. The outer

cells of the little sponge are similarly provided with whip-like arms, which have little cups into which they may withdraw for protection (Fig. 13).

In a similar way the individuals in a colony of men do not all perform the same kind of work, but some will be builders, others will grow grain and vegetables, and so on, each being especially fitted for his own work.

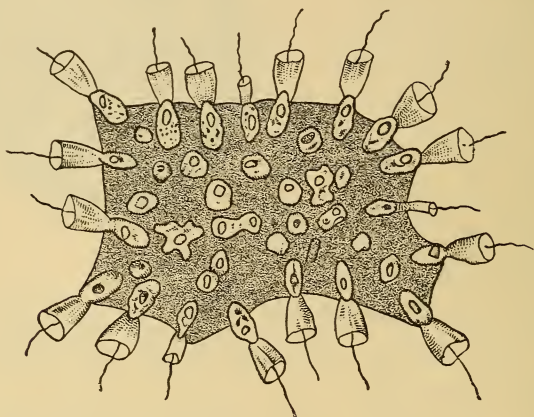


FIG. 13. — A little animal, a kind of sponge, composed of a colony of cells held together by a mass of gelatinous substance. [Verworn.]

Nature has used this principle of the colony and has produced all the higher plants and animals in harmony with the principles which govern a colony or community. The largest animal or plant is only a great colony of cells, each cell having its special work to perform. In a large colony or community of people, there will be a great many who devote their whole energy to producing the things which serve for nourishment or nutrition; others will devote themselves to transportation, carrying nourishment and building material from one place to another; others will be builders; others will be the protectors and

serve in the army or on the police force. In a similar way the cells of the digestive system of an animal are engaged in preparing food; the cells of the circulatory system are engaged in transporting this food to all parts of the body where it is needed; the cells of the cuticle, hair, nails, are engaged in protecting the body.

Any group of similar cells engaged in a similar work makes a tissue. Tissues may be composed of cells alone

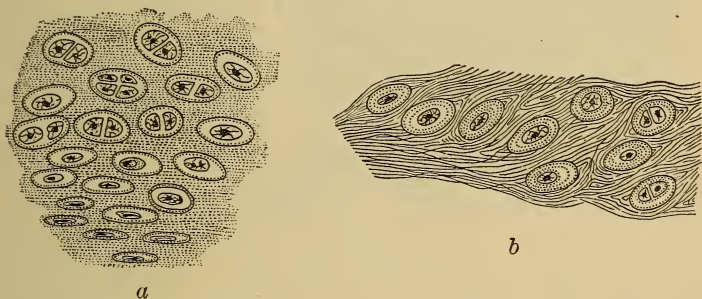


FIG. 14. — A thin slice of cartilage or gristle. Slice *a* shows the clear, brittle cartilage which is found at the ends of bones. Slice *b* shows the yellowish, tough cartilage which forms the cushions between the vertebræ. [From Miller's *Histology*.]

or of cells together with substances which the cells have formed and which they use in their work. A transportation system consists not only of the men directing it, but of their railroads, trains, and so forth. So a tissue may consist of more than the simple cell bodies. Figures 12 and 13 show between the cells a gelatinous substance made by the cells for the purpose of holding the cells together in a colony. This gelatinous substance together with the cells makes a tissue. The little plant and animal shown above (Figs. 12 and 13) are really tissues, but more complex plants and animals may be composed of many tissues.

Figure 14 shows a thin slice of cartilage or gristle as it would look under a high-power microscope. Cartilage is a tissue of the human body used principally in the joints.

Figure 15 shows connective tissue fibers woven into a network. In both the cartilage and the connective tissue the cells are of much less importance than the substance,

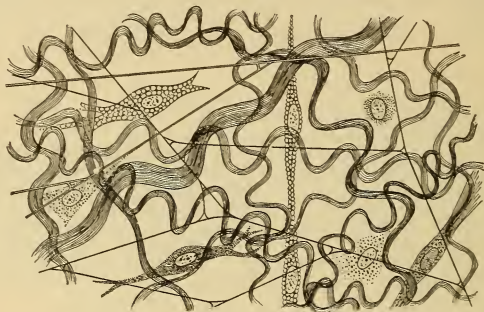


FIG. 15. — Connective or supporting tissue taken from beneath the skin. Notice that there is a loose network of wavy bundles of fibers, also a network of threadlike fibers. All of these fibers were formed by the cells which you see lying in the meshes. [Schaefer.]

matrix, or fibers, which they have formed. In fact, the work of the connective tissue cells is done when they have made the connective tissue fibers. The fibers do the work of the connective tissue.

5. ORGANS—HOW FORMED AND HOW GROUPED

IN a previous lesson the coat was likened to an organ, and its various fabrics (outside, lining, and padding) to the various tissues which compose an organ. The stomach is an organ. It is composed: (1) of a smooth, shiny outer layer; (2) of a muscular layer; (3) of a layer of loose connective tissue, like that shown in Figure 15; and (4) of a layer of cells set close together like the

blocks or bricks in a pavement. The work of the stomach is to help digest the food. To do this work of the stomach, the inner layer of cells is needed to make the digestive fluid. The connective tissue is a supporting tissue. The muscle tissue causes the churning movements which the stomach makes when it is digesting food; and the outside, smooth, shiny layer is supporting tissue which gives form to the stomach and cov-

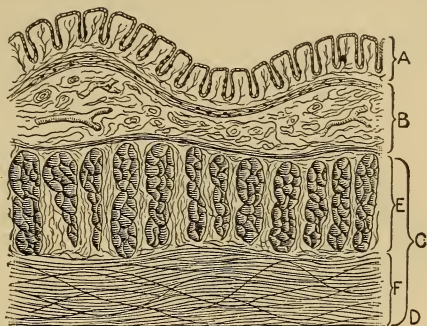


FIG. 16. — Diagram of a slice of the wall of the stomach. *A*, mucous membrane; *B*, Submucosa; *C*, muscular coat; *D*, fibrous coat; *E*, internal circular layer of muscular fiber; *F*, external, oblique, and longitudinal muscular layers.

ers the muscles to protect them. So we see that the stomach is an organ with a general work to do, and that it is composed of tissues, each of which has a special part of the work. Now each one of the tissues is composed of cells which are practically all alike. For example, all of the cells of the muscular coat are alike and all work together doing the same kind of work. All of the cells which make up the inner lining of the stomach are alike and work together to make the fluid which digests the food in the stomach. Figure 16 shows how a piece of the wall of the stomach would look under a microscope.

The intestine is an organ. Its general work is to assist in the digestion of food. It is composed of four layers of tissue quite like the stomach.

The pancreas (*pan'kre-as*) is an organ. Its work is to make a fluid which is sent through a little tube into the

intestine, where it helps to digest the food. The pancreas is a glandular organ. Glandular organs are composed of many tubes lying close together. Each tube is surrounded

by cells set together like blocks in a pavement. Figure 17 shows a very simple gland. The pancreas is composed of many hundreds of crooked tubes, all lined with cells which make the digestive fluid.

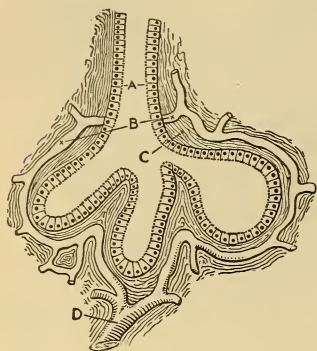


FIG. 17. — Diagram illustrating the plan of a gland. *A*, cells which line the gland; *B*, blood-vessels; *C*, connective tissue. [From Miller's *Histology*.]

SYSTEMS OF ORGANS

We have been studying organs. We found that the stomach is a digestive organ; the intestine is a digestive organ, and the pancreas also. There

are other organs which assist in digestion: the mouth, with its teeth, tongue, and salivary glands, prepares the food for swallowing; the esophagus (*e-sof'a-gus*) is the tube which carries the food to the stomach. Then the stomach and intestine hold the food while it is being digested by the fluids made in the stomach, intestine, and pancreas. All of these organs work together in the preparation and digestion of food, and we call them collectively the *Digestive System*.

In a similar way there are numerous organs which all work together to carry the blood all over the body. All of these organs taken together are called the *Circulatory System*.

The organs which work together to bring oxygen into the body and carry the carbon dioxide out of the body make the *Respiratory System*.

Remember that the general kinds of work — the general functions — of the body are performed by systems comprising several different organs; that each organ has a particular part of a general function to perform; that every organ is composed of tissues; and that each tissue assists the organ to do its work.

HYGIENIC CONDITIONS OF THE CELLS

In every normal cell is to be found matter in three conditions — the matter that is actually living, that which has lived, and that which is about to live. To maintain these three states there must be constant activity, a constant merging of the first state into the second, and the second into the third. Anything that interferes with this activity interferes with the health of the cells, with the work they have to do, and with the vitality of the tissues which they compose.

The cells cannot work actively if deprived of a sufficient amount of the oxygen of the air. Whoever sits or sleeps in close, unventilated rooms decreases the healthful activity of the cells. Whoever takes an insufficient amount of exercise does the same thing, because this leads to a sluggish flow of the blood which brings oxygen to the cells.

Some substances, when brought into contact with the living matter of the cells, stimulate or increase their activity, other substances check this, and others stop it altogether. The checking, if continued, results in the death of the cell. A few cells may die without causing the death of the tissue.

The effect of various substances upon the living cell may be watched under a microscope. If bathed with a proper food substance, the cell may be seen to expand and grow and move more actively. If bathed in an astringent

substance like tea, it shrinks up into a ball, and ceases its movements until restored. If bathed with a liquid containing a very small proportion of alcohol, its activity will cease, and, unless the proportion is very small, it cannot be again revived.

Plant protoplasm is so much like animal protoplasm as to render it likely that what will injure the one will injure the other also. Alcohol, in even small proportions, does injure plant protoplasm.

The London *Lancet* for June 16, 1900, quotes Dr. J. J. Ridge as saying that healthy cell life, both of plants and of animals, is impossible in the presence of minute quantities of alcohol. This is because the cells cannot then take in enough oxygen, and cannot cast out the waste matter from their bodies.

“Even in extremely minute proportions, alcohol prevents or retards the sprouting of seeds, and kills or stunts the growth of the seedlings that are developed. As small a proportion as one of alcohol in eight hundred of water will have a powerfully poisonous effect. The moderate drinker of alcohol dissolves in his blood, and by means of the blood conveys to the living active cells of his brain, liver, kidneys, and other organs, a much greater proportion than one in eight hundred, at least once and often several times each day.”¹

“Alcohol exerts an exceedingly harmful action on rapidly growing tissues, interfering with their nutrition, and preventing the development of their proper action. In old age, when the tissues are on the down grade, and are subject to various degenerations, alcohol, in most cases, merely accelerates the process of decay.”²

¹ Professor William Carter, M.D.

² Professor G. Sims Woodhead, Cambridge, England.

Tobacco injures the cells of the body by making them less active.

When we review what has been said about what alcohol does to living cells, we find : —

(1) The living matter in the cells of plants requires the same things for its healthy action as does the living matter in the cells of animals.

(2) What will injure growing plant cells will usually injure growing animal cells.

(3) Alcohol as found in whisky, rum, wine, brandy, or beer, even when very much diluted, will stop all healthy activity, and growth of sprouting plants.

(4) In the same way, alcohol in its various forms, and much diluted, will stop, or at least injure, the healthy activity of the cells of a young person.

(5) Alcohol is injurious to healthy cells, tissues, and organs of both plants and animals, old or young.

REVIEW OF CELLS, TISSUES, AND ORGANS

1. Plants and animals are composed of tiny particles of living substance. These particles are of various shapes and sizes, and are called *Cells*. Some cells are spherical, some are cylindrical, some are thin and flat, some are threadlike.

2. Cells are composed of *Protoplasm* which is made up of a network of living, moving *Cell plasm*, whose meshes are filled with the watery *Cell lymph*.

3. The Cell must have *food* to eat and *air* to breathe; it can *feel* and it can *move*. The cell is small when *young*; it *grows*, and *works*, and finally *dies*.

4. Cells are grouped together in *Tissues*. Some *stand side by side* like the blocks in a pavement; some *overlap* like the shingles upon a roof, and some are *woven* together like the threads in a fabric.

5. Tissues form *Organs*. Each Organ has a special work to perform; and the tissues assist in doing the work.

6. Organs are grouped into *Systems of Organs*.

CHAPTER III.—THE NERVOUS SYSTEM—HOW THE DIFFERENT ORGANS ARE MADE TO WORK IN HARMONY

1. THE NEED OF HARMONY IN THE WORKING OF THE ORGANS

WE have found that the plant or animal body is a colony of cells. We have found that, like a colony of men, some of the individuals (cells) have one kind of work and some another. Another very important point of resemblance between the two colonies is the need for harmony of action between the different individuals (cells) of the colony.

When there are only a few hundred individuals in a human colony, there is always some central controlling agency. It may be a patriarch, a chief, a sheik, a king, a czar, or a president, but in every case there is a controlling head to make decisions as to what to do next. This principal controlling agency is always supplemented by a body of individuals whose work is to assist in making decisions, or to announce the decrees or decisions to remote parts of the colony.

If a community of people were without these most important functionaries, there would be no harmony of action in time of need or of danger. Who has not seen an excited company gathered at the burning of a neighbor's house — everybody giving orders which nobody obeys; everybody busy, but little or nothing accomplished.

Presently a captain of police or head of a fire company appears upon the scene ; he is experienced in the control of fires and of men. He begins to command ; everybody gives heed and obeys. There is unity of action, there is harmony in the means used, both in the time of doing a particular thing and in the extent to which any particular work shall be done.

Think how impossible it would be to accomplish the work of a great railroad company, if there were not a central office in which plans are laid, decisions made, and commands issued. Through immediate and explicit obedience to these commands every individual, and every group of individuals employed by the company work together harmoniously for the accomplishment of the important work which they are undertaking.

In a strikingly similar way the great number of cells (individuals) which make up the human body must be controlled by some central power, or they will work at cross purposes.

Suppose the stomach should make the digestive fluid at a time when there was no food in the stomach, and suppose the glands of the mouth which make the saliva should not work when the mouth was chewing the food. Then suppose after the chewed food started down the esophagus, that tube should stop contracting ; the dry food would stick in the esophagus and have to be washed down with water. But the stomach, having already made its fluid, and passed it on into the intestines, would be dry, so that the food would be moistened only by the water which came into the stomach with it. Then the food would not digest, but would ferment in the stomach and would make the person sick.

So we see the absolute necessity of having some con-

trivance for controlling the action of all of the organs, systems of organs, tissues, and cells. When this control is perfect, the body remains in good health ; but when some portion of the body, even if it be ever so small a portion, fails to obey the commands issued by the central governing organ, the whole system is likely to become deranged and the body become sick.

The central governing organ of the human (or other animal) body is the brain. The brain is assisted by the spinal cord which lies within the backbone, and by various organs which collect news for the brain and carry the messages for it. The brain with the spinal cord and the nerves makes the *general nervous system*.

2. THE GENERAL STRUCTURE OF THE NERVOUS SYSTEM

IN bringing harmony of action among those who work for a great railroad corporation, a great army, or other large community of individuals having common interests, two things are necessary ; (1) a central controlling power ; and (2) communication from the center to all of the distant parts of the company, army, or community.

In controlling the movements of trains upon a railroad system, messages are sent along telegraph wires to conductors hundreds of miles away, directing them what to do in order that there may be no accident. If something unexpected happens in some part of the system, a message is sent to the controlling center, where action is taken to adapt the movements of trains to the new conditions.

In a strikingly similar way the animal body possesses a central controlling power in the brain. The brain is in constant communication with all parts of the body. Mes-

sages are continually being sent to all parts of the system. Telegraphic messages are sent over wires; the brain sends and receives its messages over fibers which are as fine as as those of a spider's web.

The telegraph wire is not a part of the telegraph operator, but the nerve fiber is a part of the operator whose station is in the brain or spinal cord. This *operator* is a *nerve cell*. The brain and spinal cord are composed of nerve cells with their fibers. Every nerve cell has long fibers over which it sends messages away to other nerve cells, and every nerve cell has at least one nerve fiber or arm (most have several) through which it receives messages.

When several telegraph wires are to go side by side for a long distance, they are frequently bound together into a *cable*. In a similar way the nerve fibers which leave any one part of the brain or cord to go to the same general region of the body are bound together into a cable or, as it is called, a *nerve trunk*. Nerve trunks contain, not several only, but many hundreds of the fine nerve fibers. Along the course of the nerve trunk branches are given off, which distribute the nerve fibers to different muscles and organs or to different parts of the skin along the course of the main trunk.

Figure 18 shows the general form and distribution of the nervous system. The brain, within the skull, is the controlling center. The spinal cord, which passes down an arched-over canal in the vertebral column, consists mostly of nerve fibers which carry messages to and from the nerve cells of the brain. There are relay stations all along the spinal cord where messages are received and sent out on their way to and from the brain.

All of the white lines branching off from the spinal cord

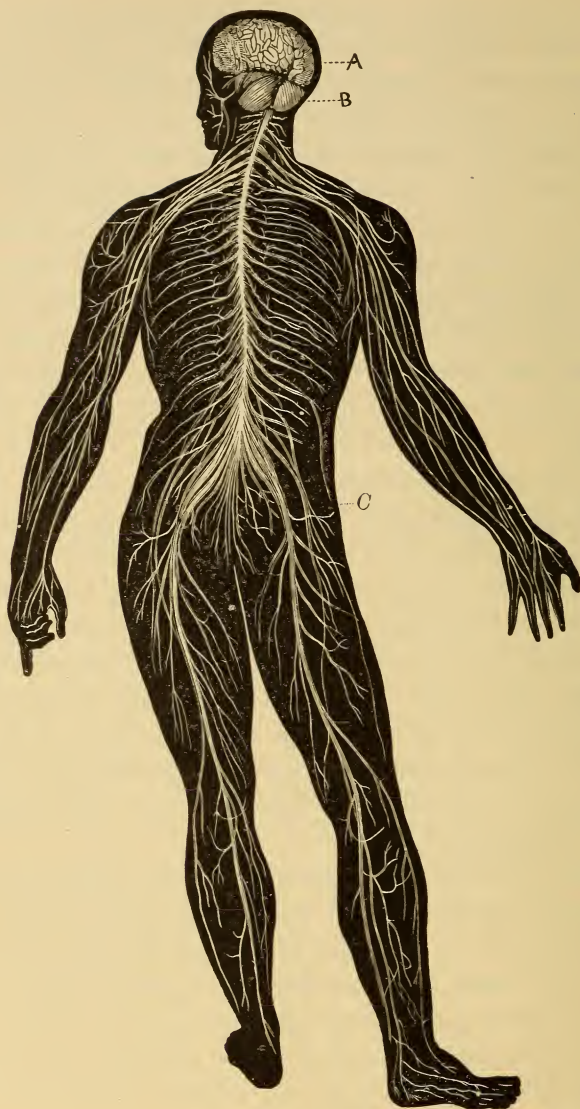


FIG. 18. — The nervous system. *A*, cerebrum; *B*, cerebellum; *C*, the sciatic nerve trunk, giving off branches as it passes down the leg.

represent trunks of nerves which lie between the muscles or under the skin of the body and limbs. But there are also nerve trunks which pass from the spinal cord inward to the body cavity, to the thorax and abdomen. There is a double line of ganglia along the back side of the body cavity. A ganglion is a relay station made up of numerous nerve cells. These ganglia are about as large as a pea or bean. Each of the ganglia in the double row, mentioned above, receives a bundle of fibers from the spinal cord. Some of these fibers bring messages to the ganglia from the brain or spinal cord, while some of them carry messages from the ganglion to the brain or cord.

Each ganglion in the chain sends out nerve

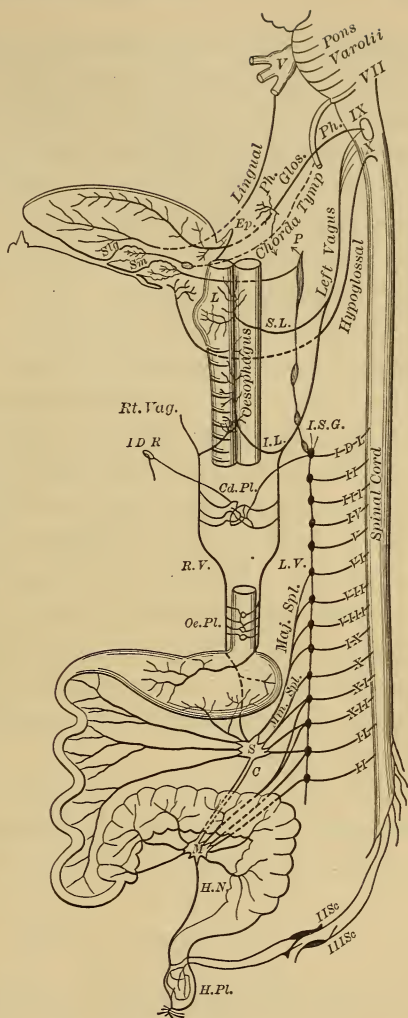


FIG. 19. — The sympathetic nervous system. Note the branches (*I*, *II*, *III*, etc.) from the spinal cord to the row of little globular masses or ganglia. A corresponding row on the right side sends branches to the large central ganglia of the abdomen, the splanchnic (*s*), and the mesenteric (*m*).

trunks to organs of the thorax or abdomen, or to large ganglia in the midst of the abdomen. These large central ganglia serve a purpose similar to that of the central exchange of a telephone system. They serve to put the organs into either direct or indirect communication with each other. Through this direct or indirect communication the activity of one organ is responded to by a corresponding activity of another. For example, the presence of food in the stomach stimulates the stomach to begin to make the churning movements, and to form the digestive fluid. This activity of the stomach causes the pancreatic gland to begin its work of making digestive fluid for the intestine to use in its digestive work. This nervous communication between the different organs of the body enables them to work together toward common ends harmoniously. Because of this sympathetic communication between the internal organs which these nerves and ganglia make they are together called the *sympathetic nervous system*. Remember, however, that the sympathetic nervous system is simply a part of the general nervous system.

Through the influence of the sympathetic nervous system, the derangement or disease of one organ may cause the derangement or disease of other organs.

3. REFLEX ACTION AND HABIT

IN the previous lesson we learned that there are relay stations along the spinal cord. A message sent from the brain to the muscles of the arm starts from a nerve cell in the brain and follows its fibers down the spinal cord to a place opposite the shoulders, where the fiber ends in a little tuft of branches which lie among the short branches

of a nerve cell in the cord. The message is communicated from the branches of the fiber from the brain to the short branches of the nerve cell in the cord, and this cell sends the message along its fiber to the muscles. If the message tells the muscle on the front of the forearm to contract, the fist will double up. When one's brain sends such a message as that, one is conscious of it. Furthermore, one knows it before the brain sends out the message ; so that one can send it or not just as he chooses.

This kind of action is called *Voluntary Action*, because one may do it or not just as one wills.

Why does one will to make a certain motion ? Suppose one were hungry and had before him a piece of food. The eyes, and perhaps also the nose, would send messages to the brain ; that is, one would *see* and *smell* the food. These *sensations* in the brain would arouse a *desire* for the food. Messages would be sent to and fro from one cell to another in the brain ; that is, one would begin to think about the food and his need for it, and finally, perhaps in a very few moments, one would decide to take the food. Messages would be sent to various muscles ; the arm would be extended, the food grasped, the arm flexed, and the food carried to the mouth, which would be opened to receive it. This is a very brief and imperfect description of all that takes place in the nervous system under such conditions. To describe it accurately and completely would require many pages. Before one stops to think about it, however, it seems to be the simplest thing in the world ; so simple, in fact, that a little baby too small to talk or to walk will perform every portion of the series of motions with faultless accuracy and grace.

Let us take another example. Suppose that one takes hold of a very warm iron poker, one end of which is in

the fire. There are nerves of sense in the skin of the hand ; messages are sent along the fibers to nerve cells which lie just outside of the spinal cord. From the cell a fiber carries the message into the cord and communicates it to another cell which carries it to the brain. When the message reaches the brain, one becomes conscious of the heat of the poker. Let us suppose that the heat is sufficient to make one uncomfortable, and fear that the hand may be burned if the hand is not removed. Messages will be sent down the cord to the proper muscles, and the hand withdrawn. There we have another example of voluntary motion following sensation.

Now when the message of sensation enters the cord on its way to the brain, it follows a branching fiber, only one portion of which goes to the brain. The other portion passes across the cord, directly or indirectly, and communicates with the nerve cells which control the muscles of the arm and hand.

Suppose one touches a very hot object, the message which is sent to the cord on its way to the brain is instantly communicated across the cord, and the nerve cell of motion, without waiting to hear from the brain, sends the message back to the arm, causing it to contract and remove the hand from danger. This saves time and frequently decreases the danger done to a part of the body.

An instant later the brain is fully conscious of all that has happened. One knows that the hand has been burned, and that it was jerked away before the brain was consulted ; but one always approves of the action.

This intervention of the cells of the spinal cord in cases of emergency is called *reflex action*. But the term has a somewhat wider application than simply to cases of

emergency. When one is learning to perform a new movement or series of movements, such as walking, skating, riding a bicycle, writing, and playing a musical instrument, each movement is a voluntary one.¹ The whole attention is required to direct the movements of the body and its different parts. Each movement is likely to be very slow and awkward. After the movement has been made hundreds of times it requires less attention, and the motions are more graceful and accurate. Finally, one may make long series of motions without giving them any attention whatever. Walking, skating, cycling, writing, or playing a piano or violin, eventually become quite automatic or mechanical.

4. REFLEX ACTION AND HABIT (*continued*)

LET us understand exactly what *automatic motion* is. The will and the thought are usually involved in automatic movements, but in quite a different way from that which is observed in the beginner who must study the details of every movement made. The practiced musician reads a measure or phrase of his score and wills to execute it as a whole, while the fingers fall into place more or less automatically to correspond with the thought in the mind of the player. In a similar way, the writer thinks words, leaving the making of each word largely to the fingers. This is especially true of the shorter and more frequently used words. The less familiar and longer words require some attention. Writing with a typewriter becomes automatic in the same way and to the same degree ; so also the use of the telegraph instrument.

¹ Of course the one who finds himself on skates or on a bicycle for the first time is likely to make a good many involuntary motions, but they are extra and not necessary, though they may be a usual part of the beginner's exercise.

What is the difference between the first labored efforts and the final automatic regularity, speed, grace, and accuracy? Practice has made one movement suggest the next, and once the combination of movements is willed and the series of movements begun, all of the details of the series become reflex and are performed by the cells of the spinal cord.

There is no one property of our systems of greater value to us than the reflex action. If it were not for this, we should have to give every step our whole attention. In fact, one could never learn to do anything gracefully, accurately, and rapidly. One would always be like an awkward, halting beginner.

Very much like this automatic action of the muscles, depending upon reflex action, is a certain property of the nervous system which we call habit.

Webster defines habit as "the involuntary tendency to perform certain actions, which is acquired by their frequent repetition." Further, "Habit is an internal principle which leads us to do easily, naturally, and with growing certainty, what we do often."

A study of this definition of *habit* must make it clear that it cannot be very different from *automatic action*. Both are acquired gradually; both make it certain that a particular series of acts will follow a particular act or thought, unless the will power of the brain is used to stop it.

Habit has a wider meaning than automatic action, and includes thoughts as well as muscular acts. One may cultivate a habit of generosity, and a habit of erect carriage while walking. One may cultivate habits of industry and habits of courtesy; habits of honesty and habits of gentleness.

Every important function of the body and mind may be diverted from the course for which it was intended by nature ; it then becomes as great a curse as it was a blessing when rightly used. So it is with *habit*. One may get a habit of stinginess, and a habit of slouchy carriage while walking. One may get habits of laziness and habits of impoliteness ; habits of dishonesty and habits of cruelty.

For every good habit there is a corresponding bad one. During youth one is always acquiring good habits or bad ones. One must do one or the other ; he has no choice in the matter. Good habits are a safeguard during all subsequent life ; bad habits are persistent enemies. It requires years of constant effort to root them out after they are once established ; but it is very easy to keep them out in the first place.

HOW THE ORGANS ARE CONTROLLED—REVIEW

1. The body is a colony or community of individual cells. Every colony or community must be controlled, or the individuals will not work in harmony, and little will be accomplished.

2. The *Brain* is the central controlling power of the body. Like a telegraph station it has operators and conductors (wires). The operators are *Nerve Cells*, and the conductors are *Nerve Fibers*.

3. The Brain *receives news* from various parts of the body, the eyes, the ears, and the skin. The Brain *sends messages* to all parts of the body,—to the muscles, the stomach, and the heart.

4. If one wishes to do something and then does it, we call the action a *Voluntary Action*.

5. If the spinal cord answers a message from the skin, causing muscles to move before the brain knows what has happened, we call the action a *Reflex Action*.

6. If one performs an act many times, it becomes *automatic* or *habitual*. Automatic and habitual acts are likely to be done without thinking. *Habits* are formed in this way.

CHAPTER IV.—NARCOTICS—THEIR NATURE, THEIR CLASSES, AND THEIR GENERAL ACTION UPON THE SYSTEM

WHEN we come to study the different systems of organs, as the digestive system or the circulatory system, we shall study not only the way in which the organs act when properly cared for, but also the various things which injure the organs. Among the things which injure the body, one of the most important is the use of narcotics. Let us devote a few lessons to the study of these substances.

1. NARCOTIC DRINKS

NARCOTIC drinks are those that dull the senses, and weaken and unsteady the muscles.

All alcoholic drinks come under this head. They are usually called stimulating drinks, because their first effect is an apparent stimulation. But they are more often taken for the dulling of the sensibilities which follows and lasts longer. It is the narcotic property which dulls the senses and produces this after-effect.

It has recently been discovered that what has always been taken for the stimulating effect of alcoholic drinks, is really caused by the narcotic effect upon the self-restraint. Alcohol is not a stimulant.

In the growth of the race from barbarism to civilization there has gradually come to be a restraint upon the

meaner traits, those which cause one to be boisterous, uncouth, and passionate. This restraint, being the last trait acquired, is the weakest and most easily attacked. The first effect of an alcoholic drink is to dull the power of restraint, and a person feels excited, which in reality means that he cares less what he does ; the next effect is to dull the senses.

No one training for feats of skill requiring strength and accuracy is allowed the use of narcotics.

Alcohol is a clear liquid which looks like water, but which burns with a blue flame, giving great heat and little light.

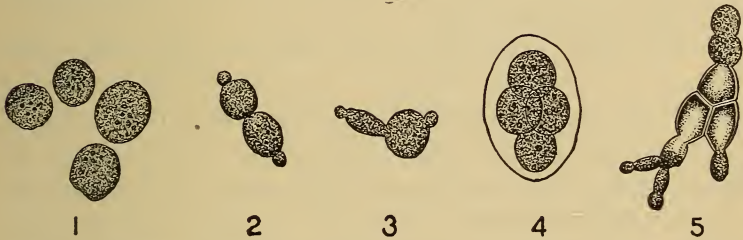


FIG. 20.—The yeast plant, strongly magnified (from Landois and Stirling).
1, isolated yeast plants; 2, 3, gemmation; 4, formation of endogonidia or spores; 5, budding of spores.

Alcohol is the result of fermentation. If one adds yeast to a dilute solution of sugar, the yeast will change the sugar to carbon dioxide and alcohol.

The yeast which produces alcoholic fermentation is a minute plant which grows especially well in sugar water. If one were to look at yeast plants through a microscope, he would find that they are spherical and live either singly or joined together in chains called colonies (Fig. 20). The principal food of this plant is sugar, which the plant breaks up in order to obtain the energy it contains. This breaking up of the sugar produces carbon

dioxide and alcohol, which the yeast throws off as waste products. If we watch the mixture of sugar, yeast, and warm water, we can see the bubbles of carbon dioxide escaping. The alcohol remains in the mixture.

In bread making we have a similar process. The starch of the flour or the free sugar which is added to it is attacked by the yeast and changed into carbon dioxide, which, in escaping from the sponge or the dough, causes the bread to bubble and become light. The alcohol remains in the mixture until it is baked, when the heat drives it off. If the bread is not sufficiently baked to kill the yeast, the growth goes on and the bread becomes sour.

When water is heated to the boiling point (212° Fahrenheit), it rapidly changes to steam or water vapor, which collects in little bubbles on the bottom of the kettle or other receptacle. The bubbles rise to the top of the water, escape into the air, and float away in a little misty cloud. When alcohol is heated, a similar change takes place, but it does not need to be heated nearly so hot before the escape of alcohol vapor begins. When alcohol and water are mixed together, as would be the case if the alcohol has been made through fermentation of sugar water, or fruit juice, the alcohol may be driven off by heating the mixture hot enough to vaporize the alcohol without vaporizing the water.

By thus heating the mixture of alcohol and water hot enough to boil or vaporize the alcohol, but not hot enough to vaporize the water, the alcohol vapor will leave the water. If this vapor is caught and conducted through pipes which are kept cold by cold water, the alcohol vapor will condense again into the liquid form, and can be caught as it runs from the end of the pipe or tube.

How similar this process is to something you have studied in your geographies! The sun warms the surface of the ocean, of lakes, and of other collections of water exposed on the earth's surface; the water is vaporized, and rising, floats away in the form of fleecy clouds. Presently these clouds pass over a range of snow-capped mountains, or pass a current of cold air. The vapor is condensed and falls as rain upon the surface of the earth.

In this way the water is separated from the briny solution of the sea; in a similar way men separate one liquid from another when the two liquids vaporize at a different temperature.

The process of separating one liquid from another by vaporizing with heat and condensing the vapor with cold is called *distillation*.

Men distill water from an impure or briny mixture in order to obtain perfectly pure water for use in the chemical laboratory or for use in manufacturing. Men distill alcohol from a mixture of various substances dissolved in water in order to get pure alcohol for use in various laboratories, for use in manufacturing, or for use by druggists in the preparation of medicines.

Many of the alcoholic drinks are prepared by distillation. They contain a much larger proportion of alcohol than the original fermenting mixture. Whisky, brandy, and rum are all distilled liquors, and contain 40 per cent or more of alcohol.

2. FERMENTATION AND DISTILLATION

ALL the alcoholic drinks are first fermented, and many of them go no further than this process. Among those which are made by simple fermentation are beer, wine, and cider.

In the beer making process, corn, or more commonly barley, is put into a damp, warm place and allowed to stay until it sprouts. We remember that in our study of the corn plant we found that, when the seed began to grow, the starch of the kernel was changed to sugar. As soon as part of the starch has been changed to sugar and dissolved out with water, hops and yeast are added, and fermentation takes place. In this condition it is bottled if it is to be used as beer, but if at this point it is put into a still and the alcohol driven off and caught, it makes *whisky*. If to the whisky certain flavors are added a drink called *gin* is made.

When sugar cane is fermented and distilled, the distilled product is called *rum*, and when wine is distilled, the product is called *brandy*.

Whisky, gin, rum, and brandy are called *ardent spirits*, and are as much as one half alcohol.

Pure wine contains from five to sixteen parts of alcohol in a hundred, but the wine that is obtained in the market often contains as much as one fourth (25 per cent) alcohol.

Beer and cider contain from four to fourteen parts of alcohol in a hundred.

Alcohol is the same wherever it is found, and the main difference in the effect of different alcoholic drinks upon the system is due to the difference in the amount of alcohol which each contains. Three glasses of some cider contain as much alcohol as one glass of strong wine or the same glass filled with one quarter whisky and three quarters water, and an alcoholic habit can be acquired from cider drinking or wine drinking as well as from beer or spirit drinking.

The great transformation which takes place in the juice

of grapes as a result of fermentation is thus strikingly summed by Professor Gaule, of the University of Zurich, Switzerland : “ Between the sweet juice of the grape which does not intoxicate and the intoxicating wine which the drinker loves, a foreign element has entered, *fermentation* ; that is, the life process of a little fungus — yeast — which feeds upon the juice of the grape and rejects the wine. That which we drink as wine has no more to do with grape juice than, for instance, the arrowroot (starch) of the plant has with the carbonic acid of the air on which it lives. The one as well as the other is a product of a chemical change which is brought about by the life process of an organism, though, to be sure, in quite the opposite sense, for the green plant cell glorifies that which it consumes, in that it forms from dead substances, carbon dioxide and water, a great source of power (sugar), while the yeast cell does exactly the opposite, consuming sugar and robbing it of most of its power, and casting out as waste substances carbon dioxide and alcohol.”

FALLACIES CONCERNING BEER

Beer has been called “ liquid bread ” from the idea that because it is made from grain, as is bread, it is therefore nourishing. In Germany this idea has found expression in the saying that “ where the brewery is, no bakery is needed.”

A saloon keeper in England once advertised his beer as “ liquid bread.” A member of the British Parliament had a chemist examine it. Two per cent was really food. Five per cent was alcohol, and the remaining ninety-three per cent was water.

Let us look into this claim a little more closely. According to standard analyses, lager beer contains: —

89.75 % water,	.15 % carbonic acid,
5.10 % alcohol,	5.00 % malt extract.

The malt extract, which is the only part that could be said to have nutritive value, consists of malt, sugar, dextrin, a very slight quantity of albuminous matter which has escaped the processes designed for separating it out, and some bitter principles and volatile oils. All that is nourishing in this could be purchased in bread for one tenth what it costs in beer.

The healthy grown person requires daily from four hundred and fifty to five hundred grammes of the kind of food that is represented in this extract in the beer. To get this amount one would have to drink eight quarts of beer, which would contain about nine ounces of alcohol. The poisonous effect of this amount of alcohol would very quickly show itself.

Professor Rosenthal of Erlanger says, "Beer is not a food, but a luxury. Let a man drink much beer, enough to make the amount of nourishment in it of value, and the other influences produced by such a quantity will become manifest to such a degree as to cast the factor of nourishment in the background. If he drinks little beer, the food value is not appreciable."

The claim is also made that the food substances in beer are "pre-digested," because they are in soluble form ready to be absorbed. Supposing there were enough of this "pre-digested" food in beer to be of sufficient importance for consideration, whatever advantages to digestion there might be in its being "pre-digested" are offset by the fact that beer retards the digestive process.

To say that substances like beer or alcohol do not need to be digested because they are already "pre-digested" is

only saying that they are in a condition to pass through the walls of the alimentary canal into the blood. This is no recommendation if it is their nature, when they reach the blood, to do harm, as is the case with beer and other alcoholic liquors.

Although certain "light beers" may contain only a small quantity of alcohol, they are by no means harmless "temperance drinks," as is sometimes urged. The London *Lancet* of April 1, 1899, asked, "Does the consumption of more beer really mean the consumption of less spirit?" and answered the question by saying, in substance: Few physicians will admit such an opinion. We certainly know of no instance in which a spirit drinker was saved by the drinking of more beer. The remedy, if not worse than the disease, is but one shade better. Beer drinkers are by no means free from the vice of spirit drinking, and are certainly not seldom the victims of the same diseases of the kidneys and liver as those which are likely to afflict the drinkers of ardent spirits.

3. THE GENERAL EFFECT OF NARCOTIC DRINKS UPON THE SYSTEM

ALCOHOLIC drinks seem to be at first stimulating, and later to have a dulling effect.

This stimulation is, however, not real, but only seeming, and is caused by the dulling of the power of self-restraint.

A civilized man restrains himself; he does not allow himself to say certain things, or to do certain things; he does not hoot and howl, he does not laugh immoderately nor weep at trifles, because he restrains himself. The dulling effect of a narcotic first acts upon this self-restraint, and a person becomes boisterous, loud, and rude. He talks

too much, and is not considerate in his treatment of others. As this dulling goes on, it affects his senses and other mental powers, so that he is not clear in his thoughts, and later it affects his muscles, causing him to reel and stagger.

The thing about wine and cider which is hard for young people to understand is, why there is harm in anything made from grapes and apples, which are both healthful fruits. But since we have seen how quickly sugar can be changed to other substances by the yeast plant, it will not be so hard to understand. If one puts a few spoonfuls of grape jelly or of marmalade into a pint fruit jar, fills it with warm water, and adds a little yeast, he will find in a few hours that it is fermenting. The sugar is being changed to carbon dioxide and alcohol. In three or four days the liquid will have changed into wine or cider, and if it is put into a still, alcohol pure enough to burn at the end of the tube may be distilled off from the liquid.

The juice of apples as it is pressed from the fruit is harmless and refreshing, but it remains so only for a few hours, after which it contains a little alcohol, which increases day by day, so that cider which at first was harmless comes very soon to be a little harmful, and in a few weeks to be intoxicating, as it then contains almost if not quite as much alcohol as beer contains.

Some think that there is no harm in drinking cider and beer. Professor Meyer, of the University of Gottenburg, says: "Naturally the lighter alcoholic drinks, such as cider, beer, and light wines, cultivate a taste for the stronger liquors and ardent spirits. Those who make statements to conflict with the undoubted facts of statistics must either be ignorant of these facts, or else they attempt to pervert them in order to apologize for their own drinking habits."

Some people think that alcoholic drinks may be indulged in moderately. Let us hear what medical men of this country and of other countries have to say about moderate drinking. "Every drunkard was once a moderate drinker, and every man who, by his example, leads other men to moderate drinking, also leads a part of them to immoderate drinking. He starts a stone rolling which it is no longer in his power to arrest."¹

"After opening the floodgate not one man in a thousand can stay the progress of a besetting vice, and of all besetting vices the alcohol habit is the most inevitably progressive. An unnatural appetite has no natural limits."²

"Experience has proved that recovery from drunkenness is possible only by *complete abstinence* from alcohol. Moderation does not help, for the taking of a small quantity of liquor causes an inordinate thirst for more."³

"Alcoholic indulgence extinguishes control. How many a pathetic story could I tell of even great and good men, the intellectual, high minded, and moral, who, confident in their power of knowing when to stop, have at last helplessly succumbed and been disgraced."⁴

The effect of alcohol upon a grown up person is bad enough; but it is even worse upon a developing person. The effect upon children is worse, because the body and brain of the child are in the process of growth. Even in the years of early manhood, alcohol is very harmful to the proper development of body and mind. Dr.

¹ Professor G. von Bunge, Professor of Physiological Chemistry, University of Basel, Switzerland.

² Felix Oswald, M.D.

³ *The Lancet*, London, June 8, 1895, p. 1468.

⁴ Charles R. Francis, in *The Medical Pioneer*.

G. H. McMichael says: "During the years of adolescence, while the brain is only partially developed, the nervous organization is not in the stable condition which marks the full vigor of normal, adult manhood. This, being so, the desire for alcoholic drinks is much more easily acquired between the ages of seventeen and twenty-five than in later life."

4. THE GENERAL EFFECT OF NARCOTIC DRINKS, ESPECIALLY ALCOHOLIC DRINKS, UPON THE SYSTEM

I. ALCOHOL A POISON

BEFORE we can properly study alcohol as a poison, we must know what a poison is. A poison is any substance which, absorbed into the blood, is capable of injuring the body, either by causing damage to the tissues or by producing functional disturbances. From this definition we see that a poison may disturb the mode of action of the tissues or organs without causing permanent damage to these structures, or a poison may injure the system by changing the structure of the tissues. Allbut's "System of Medicine" says, alcohol "acts directly on the nerves as a functional poison," and Professor Woodhead says: "Alcohol exerts an exceedingly deleterious action on rapidly growing tissues, interfering with their nutrition, and preventing the development of their proper function. In old age, when the tissues are on the down grade and are subject to various degenerations, alcohol in most cases merely accelerates the process of decay."

Professor Fick, of the University of Wurzburg, in Germany, defines a poison as any substance which, being mixed with the blood, causes a disturbance in the functions of

any organ, and adds, "that alcohol is such a substance cannot be doubted." He calls the attention of his countrymen to the fact that "the English language appropriately calls the disturbance caused by alcoholic drinks *intoxication*, which by derivation means *poisoning*."

Professor Forel, of the University of Zurich, Switzerland, says: "Alcohol, even when diluted, as in wine, beer, and cider, is a poison which changes the active tissues of the body, causing them to become fatty, either by having fat deposited in them or by the changing of the tissues themselves to fat. Even in such small amounts as a glass of wine or a pint of beer taken with meals, it is injurious because it injures the brain by dulling its activity and deranging its functions. This has been clearly demonstrated by the experiments of numerous investigators.¹ The most moderate drinking of alcoholic beverages is quite useless for anybody, and by means of the example produces very great injury to the people in general, because many will be led to drink who would not otherwise have done so, and of the many who begin as moderate drinkers, few will remain moderate drinkers."

II. INFLUENCE OF ALCOHOL UPON THE BODY

"France presents a splendid illustration of a country whose inhabitants made free use of alcoholic drinks, beginning usually with light wines. And as a result, this great country, with its beautiful climate, its fertile soil, and other material advantages, equal to the most favored portion of the earth, at the present time actually depends upon immigration to keep up the numbers of its population. The leading men of France are seriously studying the ques-

¹ Such investigators as Kraepelin, Smith, Fürer, Aschaffenburg, and others.

tion, 'How to prevent the depopulation of France?' The French nation, descended from a race of gigantic Gauls, who struck terror to the hearts of their enemies by the very magnificence of their presence, has declined to such a degree from the stunting influence of alcoholic and similar drinks upon their growth, that the average height of the people at the present time is actually less than that of other civilized nations. The facts witnessed in wine growing districts and in wine growing countries certainly do not commend the universal use of wine as a remedy for intemperance — a use for which it has been suggested."¹

According to Dr. Brunon, the population in Brittany is being rapidly decreased through the use of alcohol. Alcohol has become a part of the regular table supply of the home. Coffee and beer, or some other alcoholic drink, form the basis of the dinner; and if one of these must be omitted, it is the coffee. The most distressing feature of the case is the serious effect that this use of alcohol has on the young. The death rate of young children is very great, such as is met with nowhere else.²

The Consular Reports of 1895 quote a writer in *Le Havre* as saying, —

"Alcoholism is the great misfortune of the present day, and if the evil is not corrected, France will be changed into a nation of brutes by this ignoble vice. The peril is evident, and it is high time to check it. I know that the infamous vice is not peculiar to our country, but I see that its ravages are greater here than elsewhere."

"The workingmen, women, and children of our country absorb, in its various forms, a poison which filters

¹ J. H. Kellogg, M.D., *Journal of Medical Temperance Association*, October, 1897, p. 126.

² From the *Normandie Medicale*, quoted in *Medical and Surgical Reporter*.

through their bodies, which, even in small doses, daily repeated, breaks the strength, paralyzes the nervous system, destroys the intelligence, and makes the drinker grow prematurely old. It makes in a few years, sometimes even in a few months, of an individual once robust, active, and a valuable member of society, a being abject, degraded, and infirm. *This poison is alcohol.*"¹

By strict persistence in total abstinence and hygienic living the children of drinking parents may overcome the tendency to defective conditions of body and mind, to which they are especially liable. A weak will with which to resist temptation is frequently part of the inheritance which children receive from alcoholic parents. But even such a will may resist the first glass, and in this way gain strength for continued resistance of temptation as well as uprightness of character in all directions.

5. OTHER NARCOTICS

I. TOBACCO

CIGARS, cigarettes, smoking tobacco, chewing tobacco, and snuff are all made from the dried leaf of the tobacco plant.

Tobacco contains a sharp-tasting liquid called nicotine, which is a quick-acting and deadly poison. Because of this poison, the juice of the tobacco is never purposely swallowed; but in chewing, the saliva dissolves the nicotine, and a part of it is absorbed into the system; while in smoking, the nicotine in the smoke and vapor is absorbed

¹ A. Motet, M.D., of Paris, Member of the French Academy of Medicine, in an address before the VI International Congress against the Use of Alcoholic Liquors. Report of Proceedings.

by the saliva and the moist membranes of the mouth and nose, and taken into the system, where it exerts all of its harmful effects, among which is an irritation of all the membranes with which it comes in contact. After a time, the narcotic effect dulls the sense of feeling, so that the irritation, while it still exists, is not felt. This poison in the system makes one less able to throw off disease, and some of the best insurance companies are refusing to insure tobacco smokers.

The cigarette, being a cheap preparation, tempts boys to indulge more in this than in any other form of tobacco. While tobacco is injurious to every one, it is far more harmful to those who are growing. All physicians agree in saying that a boy who uses tobacco can never be so large or well-developed a man as he could have been without it. He can never have the strength of body nor the vigor of mind that he would have had except for the use of tobacco.

All physicians agree in saying that no one should begin the use of tobacco before the age of eighteen or twenty years. If a boy waits to that age before beginning its use, the chances are his judgment will be sufficiently matured to keep him from it.

II. OPIUM

There are other narcotics that have a medicinal value, that have also the power of creating a desire for the drug, which in its increasing use is fatal. Such drugs are opium, the dried juice of the white poppy; morphine, a white powder made from opium; and laudanum, a solution of parts of the opium in alcohol. A habit of using any of these narcotics is almost impossible to break, and its effects are very serious.

Paregoric is a weak form of opium in alcohol, and should be taken only by prescription from a physician.

Soothing syrups also contain opium, and should not be given to children, as they do not cure but simply stupefy the child.

What has been said in the preceding lessons about the influence of alcohol upon the will power, applies with equal truth to such narcotics as tobacco and opium. The enslaving influence of opium is even greater than that of tobacco or alcohol.

The secret of the power of these things over a person who has become addicted to them is that they rob the person of a part of the will power, and will power is the very thing that is required in order to enable the victim to break the habit.

In the chapter on the nervous system, we found that *a habit is a blessing, if a good one, and a curse, if a bad one*, because the habit is made possible only through a change in the nervous system. When the habit has once been formed, it requires many months, perhaps years, to break it. It requires the constant exercise of the will power. How is one to fight a habit on equal terms, if through the habit he has been robbed of a part of his fighting equipment?

Young men who are in training for athletic contests where strength, alertness, skill, and accuracy are required, are positively forbidden by the managers of the teams to use tobacco or any other narcotic, and boys and young men entering the employ of a great business house or a corporation where their success depends upon strength, alertness, skill, and accuracy, as well as integrity and industry, would surely reach a much higher success if they abstained totally from all narcotics.

REVIEW OF NARCOTICS

1. *Narcotics* are substances which dull the senses and the sensibilities. The most common narcotics are the *Alcoholic Drinks, Tobacco,* and *Opium*.

2. Alcoholic drinks are made by *Fermenting* sugar with yeast. *The yeast eats the sugar and throws out carbonic acid gas and alcohol as waste matter.*

3. Drinks which are prepared by the fermentation of fruit juices or of grain sugars are called *Fermented Drinks*; examples are, *wine, cider,* and *beer*.

4. Drinks which are prepared by the distillation of the fermented liquors are called *Ardent Spirits*; examples are, *whisky, brandy, gin,* and *rum*.

5. Alcoholic drinks seem to stimulate at first because they *dull* the brain control and the self-restraint.

6. *Alcoholic drinks dull all of the senses and all of the sensibilities, weaken the will power, and create a thirst for more alcohol.*

7. The moderate use of alcohol is very likely to lead to the immoderate use of it.

8. The immoderate use of alcohol causes disease, degradation, misery, and crime.

SPECIAL PHYSIOLOGY

UNDER General Physiology and Hygiene we have studied briefly the physiology of a plant; we have studied the cells and tissues of which the organs and systems of organs are built up; we have studied the means by which the organs are controlled and made to work together harmoniously; and we have studied some of the more important things which harm the body through injury to the tissues or through derangement of the functions.

We are now prepared to enter upon a detailed study of each system of organs of the human body. This part of physiology is called *Special Human Physiology*.

CHAPTER V. — NUTRITION — HOW THE BODY IS NOURISHED

THE term *Nutrition* is used in physiology to include all of the work that tissues and organs do in the *Preparation of Food* for absorption, which includes *Mastication*, *Swallowing*, and *Digestion*, the *Absorption* of food and the *Assimilation* of food, under which head one studies how food material is built up into the living active tissues of the body, as well as the oxidation of food material and of tissue material. One may, under the head of Nutrition, study *Foods*, as well as those parts of domestic economy which deal with the *choice* and *preparation of food*.

1. WHY WE EAT

IF you have ever watched a locomotive in motion, you must have seen the fireman putting fuel into the firebox. You know just as well as the fireman does that if he should stop putting coal on the fire the engine would stop going. He knows something which you do not know, and that is, how much coal to put on to make the engine go a given distance.

Many railroad companies and many large factories analyze coal from different companies before they buy, in order to know which coal will give the most heat and motion per ton or per dollar's worth.

The amount of heat and motion which a fuel produces can be exactly measured. The coal which is used in the locomotive becomes oxidized and changed into carbon

dioxide and water, with smoke and ashes left over. The oxidation of the carbon of the coal causes the heat to be given off. The heat under the boiler produces from the water steam, whose pressure in the cylinder moves the piston and turns the wheels. The engine itself is not built up by the fuel which it consumes, and it gradually wears out.

We take food into our bodies to supply heat and motion, and if the food be tested we can tell exactly how much heat and motion it will give. In the experimental station at Washington and in many laboratories, men are at work finding how much energy can be obtained from different foods when prepared in different ways.

Food will give the same amount of heat and motion when burned in a furnace as when consumed in the body.

If the government wished to move an army of men from one city to another, it could either feed the men on nourishing food and give them a long time in which to walk there, or it could use the same food in an engine, which would carry the men on a train in much less time. In this case some extra food must be given the men to keep them warm, as the heat which would be enough to do this is lost from the engine. Bread is, however, too bulky to carry and too expensive to burn, so instead of bread we use in a locomotive a fuel like coal, which takes up less room and costs less.

A loaf of bread burned in a furnace and one consumed in the body give out exactly the same amount of heat and motion. The food which we consume is changed into fluid form, and then goes to build up tissues just as it does in the plants.

In selecting coal, the buyer chooses that which gives the

most power for the money, without regard to the looks of the coal or the color of the flame.

In choosing food to supply our bodies with heat and motion, what should we think of first? Should it not be the amount of power it contains? In other words, food should be chosen to give the most nourishment for the least money, provided it can be made to look well enough to be appetizing and taste well enough to be palatable. Here comes in the work of the cook, who can choose and prepare the food, and add the seasoning and the decoration.

We should think an engineer very wasteful if he used more coal than is necessary to make his engine do the work he needs. Is it not equally wasteful for us to eat more than we need for our work simply because it tastes good and we enjoy it?

That which is harmful should not be eaten, although we may like it. That which is nourishing should often be taken, even though we do not like it. If one thinks of the good which a wholesome and nourishing food will do the body, instead of thinking whether the taste is most pleasing to him, he may readily cultivate a real liking for a food which might at first seem distasteful.

2. WHAT WE EAT—FOODS

I. EGGS AND MILK

WE have decided that food shall be chosen first for the energy it contains, and to do that best we must know of what different foods are composed.

Let us look first at the egg, for in this we have what is to the animal world just what the seed is to the plant world. If we examine an egg carefully, we find an outside shell that corresponds to the shell of a nut. Underneath

the shell we find a tough skin like the skin that covers all seeds; inside the skin a white fluid and a yellow fluid which are the food, and just under the very thin skin of the yellow part or yolk we see a white spot with a ring around it, which is the germ or young chick. The young chick is surrounded by the food which it will need when it wakens to life, just as the young plant is. Both the plant germ and the chick germ are sleeping protoplasm. They sleep until the heat wakens them to life. The seed needs also moisture to soften the food, but the egg is already supplied with water enough.

The yolk of the egg is so balanced that the germ spot is always up whichever way the egg is turned. In this way the germ is kept next to the heat which the mother hen supplies from her body when she sits on the eggs. The yolk of the egg is proteid and oil, with some mineral matter. The oil gives it the yellow color. The white of the egg is pure albumen, or proteid with mineral matter and water.

From these materials are built up the bones, muscles, blood, nerves, and feathers of the chicken.

The egg is nature's food for young birds. Is it a good food for us? We need bones, muscles, blood, nerves, and hair, and if the egg will build up these tissues in a bird, it will also build them up in us. It is, however, such condensed food that it cannot be used alone for the food of an adult, and not at all, or at most sparingly, for a child under one year old. When the egg is raw, it is easily digested, but when cooked, it becomes hardened and is more difficult to digest.

Nature has supplied in milk a food for the young of higher animals. This food exactly fills the need of the young child, and contains everything that a child requires

for its first year's growth. Let us see what materials milk contains. The part that makes it liquid is water, the sweetness comes from sugar, the cream which rises to the top is oil, and the rest is proteid and mineral matter. You can see that milk alone would sustain life for a long time.

II. EXPERIMENTS

You still have a supply of iodine obtained for the experiments in plant physiology. Some of the iodine has its original strength, while some is diluted.

Get from the druggist or from a physician a few ounces of Fehling's Solution (composed of a mixture of copper sulphate, or blue vitriol, and potash).

Get also a few four inch or six inch test tubes. They are made of thin annealed glass, and may be heated in a flame without danger of breaking. If there are no Bunsen gas burners in the school building, a common kerosene lamp can be used with good results.

1. Take a few drops of albumen or white of egg in a test tube, dilute it with a spoonful of water, and heat it over a flame. It will soon begin to turn white and to thicken, or *coagulate*, as it is called.

2. Take a spoonful of milk and heat it in a similar way. It will not coagulate.

3. To a spoonful of milk add a few drops of lemon juice or any other acid. The milk will coagulate.

The small masses which separate out from the milk are called *coagula*, and consist of *casein*, the principal proteid of the milk. When milk is heated, one may notice a thin, wrinkled membrane collecting upon its surface. This membrane consists of albumin (milk albumen), which is the other proteid of the milk.

The yellowish part of the milk which can be drained away from the casein coagula is the *whey*. Whey consists of water, milk sugar, and mineral matter, with perhaps some cream or fat. Most of the fat stays with the casein when it separates out in coagula.

4. Put into a test tube as much grape sugar (dextrose) as will stay on the tip of a penknife blade, add a spoonful of water to dissolve it, add an equal amount of Fehling's Solution, bring the mixture to a boil over a flame, and notice the orange or brick-red, heavy precipitate which first clouds the mixture, then settles to the bottom of the tube. This is copper oxide, which separates out of Fehling's Solution when that is heated with a solution of dextrose, or of milk sugar (lactose), or of malt sugar (maltose).

5. Put a spoonful of whey into a tube, and add an equal amount of Fehling's Solution. Heat it over a flame, and note the separation of the copper oxide, again showing the presence of dextrose, or lactose, or maltose. In this case it was *lactose*, or milk sugar. So milk contains proteid, sugar, and fat.

3. WHAT WE EAT

I. CEREALS

GRAINS which are used for food are called cereals. They belong to the grass family, and form an important part of our food.

Corn, wheat, oats, barley, rye, and rice are cereals, and from these we get corn meal, cornstarch, wheat flour, graham flour, oatmeal, barley, rye flour, rice flour, and various other meals, flours, and prepared "breakfast foods."

If we look at a grain of each of the cereals, we find they all have a skin covering the grain. The oats, barley, and rice have a tough, chafflike skin, which is always removed before it is put on the market for food. Barley and rice are so seldom seen with the skin on that we think of them always as white grains.

Under the skin of the wheat and rye, oats and barley, is a brownish or yellowish coat that is very rich in proteid and mineral matter, while the inner part of the seed is starch containing some proteid and mineral matter. At the end of the kernel and on the opposite side from the long groove we find the germ, which is of protoplasm and very nourishing.

Most of the proteid part of these small grains, especially wheat, is a sticky substance called gluten, and it is this gluten which makes many of the wheat breakfast foods seem sticky when cooked. In white wheat flour we have the starch with some gluten and mineral matter. In "whole wheat" or "entire wheat" we get the starch and all the gluten and mineral matter from the brown coat, as it is not bolted; and in graham flour we get all the contents of the grain and the skin as well. There is no nourishment in this skin, but it makes the flour coarse, and thus excites or stimulates the formation of digestive fluids, as well as the movements of the stomach and intestine.

It is sometimes said that white bread is not nourishing; that you can see is not the fact, but you can see equally well that the whole wheat and graham flour is much more nourishing to the whole body, and especially to the bones and teeth, as the greater part of the mineral matter lies in the brown coat which is bolted out of the white flour. Growing boys and girls need much of the bone making

material to be found in whole wheat and graham flour, in the cereal breakfast foods and in corn meal.

Great care should be taken in the preparation of cereal foods, for unless they are well cooked they are hard to digest, and some of the nourishment is lost. Some of these cereals are said to need two minutes' or fifteen minutes' cooking, but in every case the food is much improved in wholesomeness by at least thirty to forty minutes' cooking.

II. EXPERIMENTS

Soak some grains of corn, wheat, oats, rye, barley, and rice in warm water for two or three days.

1. With a penknife and a strong needle dissect off the thick, husky, outside shell of a kernel of oats and barley.

2. Dissect off the thin, transparent skin of corn, of wheat, and of rye. Find the germ of each kernel. Make some thin slices across each kernel, and draw a figure showing the location of the germ, and the food material which the parent plant stored for the sleeping young plant.

3. Place a slice from each grain into a few drops of the dilute iodine in a watch crystal, and notice the blue color, showing both the presence of starch and its location in the kernel. Notice that the germ and that part of the kernel in its immediate vicinity do not turn blue, and, therefore, contain no starch.

4. Put slices of each grain into strong iodine, and after they have been acted upon for several minutes, rinse off the iodine. Notice that the starch is turned to a very dark blue and the germ and its surrounding food material to a brownish yellow. Strong iodine turns proteid matter this color. The oil is mixed in with the starch and proteid,

and is not so easily shown by a simple experiment. If a kernel of grain be burned, a small amount of ashes remaining will represent the mineral matter.

Remember that cereals contain starch, proteid, oil, and mineral matter.

4. WHAT WE EAT (*continued*)

I. VEGETABLES

IN our study of the cereal foods we found that they contain all the kinds of nourishment. They alone can sustain life. There is another class of foods which we call *legumes*. These are the beans, peas, and lentils. These also are rich in proteid and starch, and have some oil, mineral matter, and cellulose, and like the cereals form a perfect food, but in such condensed form as to need something else to help them through the digestive tract.

There is still another class of foods which gives nourishment in a much less condensed form and provides the variety which we need to give relish to our food. This class includes the vegetables.

Let us taste a bit of beet, turnip, parsnip, carrot, and of onion, and in all of them we shall notice a sweet taste. These vegetables we eat for the sugar they contain, and for the mineral salts, which we cannot detect by taste. They contain also a large amount of cellulose, which has no nourishment, but which, by stimulating the digestive organs, helps them in their work. If we taste a piece of white or sweet potato, we shall notice that it is rough to the tongue and has a raw taste. This is due to the presence of starch. The sweet potato has some sugar in addition to the starch.

All of these vegetables which contain starch or sugar are

very nourishing, but cannot be used alone as food, as they have almost no proteid and oil. Because of this lack of these substances, many vegetables are prepared with milk and butter in the cooking, and are in this way supplied with oil and proteid.

Such vegetables as cabbage, lettuce, celery, spinach, and other greens are used largely as a relish, and contain almost no nourishment. They are, however, very important as a relish, and some of them have other uses. Lettuce and celery have a juice that is soothing to the nerves, while spinach and other greens contain more iron than do other vegetables.

Besides these vegetables, there are some vegetable products that are very valuable as food stuffs. Among these are potato starch, cornstarch, arrowroot, sago, and tapioca, which are almost pure starch. The first is the extracted starch of the potato, the second of the corn kernel, while arrowroot and tapioca are from the underground stem of tropical plants. Sago is from starch deposited in the trunk of the sago palm.

The vegetable products that are pure sugar are beet sugar, cane sugar, grape sugar, maple sugar, molasses, and syrups. All sugars and syrups, with molasses and honey, are very nourishing and for most people very wholesome.

As potatoes contain principally starch, we usually add a little butter and milk to them or eat them with meat and gravy. Milk and butter are also often added to beans, peas, parsnips, carrots, cabbage, celery, and onions.

Macaroni, which is made from flour and water and contains as much proteid as wheat supplies, is still largely starch, but when cooked with milk, butter, and cheese contains all the elements of food.

II. EXPERIMENTS

1. Make a careful dissection of a soaked bean, and of a pea, making a drawing to show the thin skin and the two halves of the kernel, which represent the seed leaves. Find the tiny stem and rootlet of the germ plant.

2. Make thin slices of the soaked kernels and treat them with dilute and with strong iodine, and note the results.

3. Make thin slices of turnip, parsnip, carrot, and onion, and test one kind of vegetable at a time by putting a slice into a test tube with a spoonful of water and of Fehling's Solution. Heat to boiling over a flame, and notice that the slice turns a brick-dust red or orange, showing the presence of sugar (dextrose).

4. Test the same vegetables with dilute and strong iodine, and notice that there is no starch and no proteid, except perhaps, a little proteid just under the skin.

5. Test slices of white and sweet potato for sugar and for starch and proteid. Note results.

5. WHAT WE EAT (*continued*)

I. FRUIT

ALL the foods we have talked about, with the exception of milk and eggs, have been vegetable products, and the fruits also belong here. Among the many fruits, we find some much sweeter than others. These are eaten largely for the sugar they contain and their healthful effect upon the digestion. Such fruits are apricots, peaches, pears, plums, cherries, grapes, and some apples. Bananas are rich in sugar, but lack the refreshing juices of the other fruits.

Oranges, many apples, quinces, and crab apples are chiefly valuable for their acid, although they also contain sugar.

The lemon and lime have no sugar, but are very important foods because of the acid and salts which they contain.

Fruit is especially needed in the summer weather and in warm climates, while fats are needed in cold weather and in cold climates.

II. MEAT

As yet nothing has been said of animal food, and we have already seen that life could be sustained without any animal food, for it contains no new material. It does, however, contain the most nourishing kind of food in a condition easy to use. Meat is composed of proteid matter and fat, held together by connective tissue, such as bone, gristle, and so forth. We are likely to think that porterhouse steak at twenty-five cents a pound is more nourishing than other cuts of meat at six or ten cents per pound. If both are broiled, it is true the porterhouse steak will yield more nourishment, but the cheaper meats by long cooking become equally nourishing, because the cooking changes the connective tissue to gelatine, which is proteid food.

Have you not noticed when the water in which a soup bone has been cooked becomes cold it looks like jelly? That comes from the changed connective tissues of the bone, gristle, etc. Let us make some menus that will contain a healthful variety and yet give all the elements of food at a low price.

PHYSIOLOGY

MENU NO. 1

BREAKFAST.

Cereal food.	Milk.
--------------	-------

LUNCHEON.

Omelet.	Creamed potatoes.
Brown bread.	Apple sauce.

DINNER.

Potatoes.	Spinach.
Grapes.	

MENU NO. 2

BREAKFAST.

Soft boiled eggs.	Bread and butter.
Cereal coffee.	

LUNCHEON.

Made dish of rice and meat.	
Prunes.	Bread and butter.

DINNER.

Pork and beans.	Tomato sauce.
Potatoes.	
Sliced oranges.	

MENU NO. 3

BREAKFAST.

Milk toast.	Cereal coffee.
-------------	----------------

LUNCHEON.

Cold meat.	Sliced potatoes.
Graham bread.	

DINNER.

Carrots.	Potatoes.
Baked apples with cream.	

REVIEW OF FOODS

1. Nature's food for the young of higher animals is *milk*.
2. Nature's food for little chickens or other birds before they are hatched is egg. Eggs and milk contain all that the body needs for its growth and development.
3. Milk and Egg contain *Albumen*, or *Proteid*, and *Fat*, and *Water*, and *Mineral Matter*. Milk also contains *Sugar*.
4. The *Grains* or *Cereals* contain *Starch*, *Fats*, *Proteid* or *Albumen*, and *Mineral Matter*.
5. *Peas* and *Beans* contain starch, oil, mineral matter, and are very rich in proteid. People who eat no meat use milk, eggs, and peas or beans freely in order to get enough proteid.
6. Some fruits are full of sugar and are, therefore, very nourishing: grapes, peaches, plums, cherries, etc.
7. Some fruits are acid and are refreshing and wholesome in summer: lemons, oranges, apples, etc.
8. Meats are usually eaten freely though they are not necessary, because the vegetable foods with milk, eggs, butter, and cheese make a sufficient and perfectly wholesome diet. Meats are rich in proteids, fat, and mineral matter. The expensive meats are not more nourishing than the cheaper cuts.

6. THE STRUCTURE OR ANATOMY OF THE DIGESTIVE SYSTEM

THE *Digestive System* consists of the *Alimentary Canal*, with certain glands whose ducts or tubes open into the canal. The alimentary canal consists of a series of hollow or tubular organs through which the food passes during the process of digestion and absorption. Beginning with the *mouth* the food passes down the *esophagus* into the *stomach*. (Make a careful study of Fig. 21 while reading this description). After it leaves the stomach it passes through the coiled *small intestine*, which is subdivided into *duodenum*, *jejunum*, and *ileum*. Passing from the

ileum into the *large intestine* through a small opening it comes into the *cæcum*, then passes upward, across, and downward through the *colon* into the *rectum*. (Compare Fig. 22 with Fig. 21).

The glands of the digestive system are the three pairs of *salivary glands* (the *parotids*, the *sublinguals*, and the *submaxillaries*), the *pancreas*, and the *liver*. The liver, however, has little to do with digestion, and much to do with assimilation and excretion. Let us now look carefully at each of these organs of digestion, and see how each is made and what part of the work of digestion each performs. The

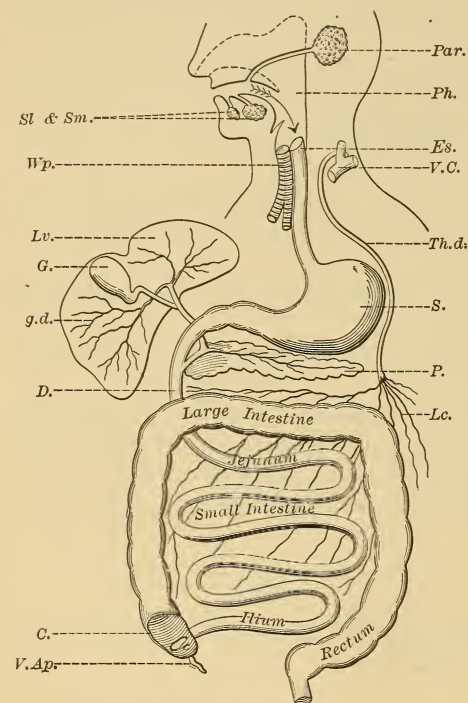


FIG. 21.—A diagram of digestive system. *Par.*, *Sl. & Sm.*, parotid, sublingual, and submaxillary glands; *Ph.*, pharynx; *Es.*, esophagus; *V.C.*, vena cava vein receiving chyle through thoracic duct (*Th.d.*) from lacteals (*Lc.*); *Lv.*, liver; *P.*, pancreas; *S.*, stomach; *D.*, duodenum; *C.*, caecum; *V.Ap.*, vermiform appendix.

mouth cavity is formed by the cheeks, the lips, the tongue, and the palate; the latter has an upper part hard and bony, which extends back into a softer part from which the uvula hangs down. Between the cheeks are the teeth, whose office it is to masticate the food and mix it with

the saliva. There are two sets of the teeth, the temporary set of twenty teeth, which is lost at about six years, and the permanent set of thirty-two teeth (Fig. 23). There are three parts to be distinguished in a tooth: the crown or part seen in the mouth, the root or part which projects into the gums, and the line between which is called the neck.

The teeth are composed of a hard, shiny, outside layer called the enamel, which acts as a protection to the teeth, the middle bony part or dentine, and the inner soft part or pulp, largely composed of blood vessels and nerves (Fig. 24).

Beginning in the middle of the jaw, one finds on each side of each jaw two cutting teeth or *incisors*, one tearing tooth or *canine*, two semigrinding teeth

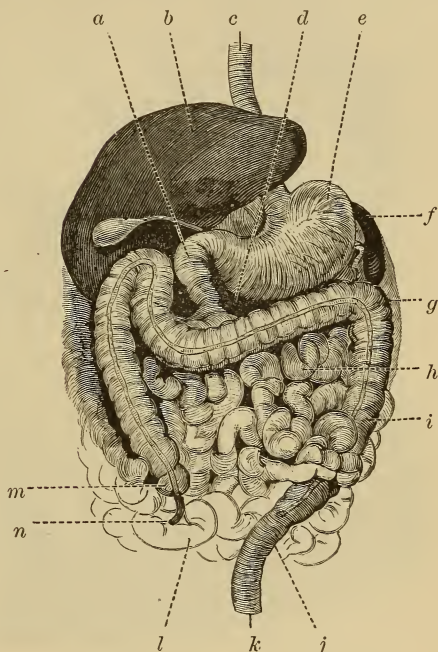


FIG. 22. — Picture of the organs of digestion. *a*, duodenum, leading out of the pylorus; *b*, liver; *c*, esophagus; *d*, pancreas; *e*, stomach; *f*, spleen; *g*, *i*, *j*, *k*, *m*, *n*, parts of large intestine; *h*, *l*, small intestine. [From Johownot and Bonton.]

called *bicuspid*s, and three grinders or *molars*. Most of the teeth have a single root, but the molars have two and sometimes three roots or fangs. The saliva, which mixes with the food during the mastication by the teeth, comes from three pairs of salivary glands: the *parotid gland*,

situated in front of the ear; the *submaxillary*, situated under the jaw; and the *sublingual*, under each side of the tongue. These glands make or secrete the saliva and give it out when stimulated by the presence of food in the mouth, or even by the thought of food. The pharynx is

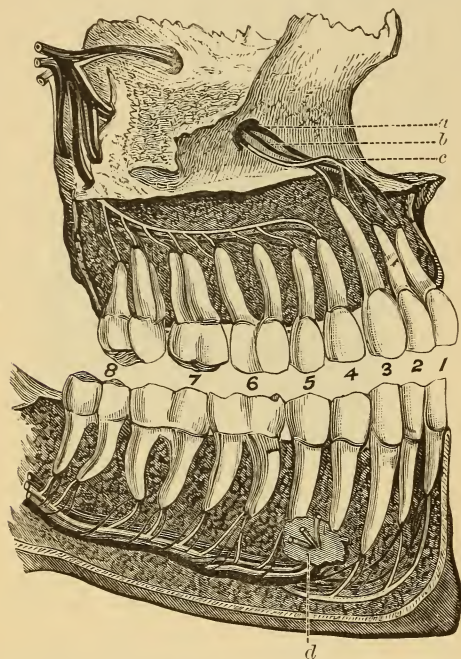


FIG. 23. — The jaws and the teeth: 1, 2, incisors; 3, canine; 4, 5, bicuspids; 6, 7, 8, molars; a, vein; b, artery; c, nerve; d, vein, artery, and nerve. [From Johownot and Bonton.]

supplied with two doors which prevent the food from getting into the wrong passages. In order that the food may not go into the nasal passage the uvula and soft palate turn back during the process of swallowing and cover the opening; and that it may not go into the air tube, a little guard, the epiglottis, protects the opening of the air passage. This is done very quickly, for during the process of swallowing one cannot take breath. One

does occasionally try to breathe and swallow at the same time, with the result of getting food into the windpipe, causing violent coughing until it is expelled. The esophagus is a long tube which has a soft mucous lining and a muscular coat of circular bands. In forcing the food along the esophagus the muscular bands do not con-

tract all at once, but in succession, beginning at the pharynx. The first contracts and makes the passage smaller, and thus pushes the food on to be contracted upon by the next band. This motion is called *peristaltic action*. The same kind of motion carries the food along the whole extent of the alimentary canal.

7. ANATOMY OF THE DIGESTIVE SYSTEM

(continued)

THE *Stomach* is a pouch which holds about a quart or three pints; the opening between it and the esophagus, being near the heart, is called the *cardia*, and the one from the stomach into the intestines is the *pylorus*. Both of these gateways are supplied with circular muscles which by contracting close the opening. The cardiac end of the stomach is the storage part, and the gastric juice secreted by this end is somewhat different from the gastric juice secreted by the pyloric end, which does the work of churning and digesting the proteids (Fig. 25).

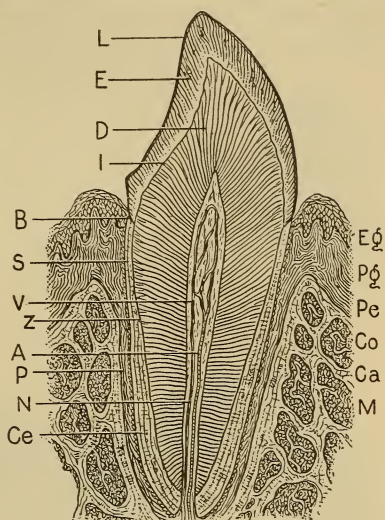


FIG. 24. — Diagram of the structure and setting of a normal incisor tooth. [Bödecker.] *L*, cuticle of enamel; *E*, enamel; *D*, dentine with canaliculi; *I*, layer between enamel and dentine; *B*, border-line between enamel and cementum of neck; *S*, cementum of neck; *Ce*, cementum of root; *Z*, layer between dentine and cementum; *P*, pericementum; *A*, arteriole of pulp, branching into capillaries; *V*, vein of pulp taking up capillaries; *N*, medullated nerve-fibres of pulp; *Eg*, epithelium of gum; *Pe*, periosteum; *Ca*, bone tissue of alveolus; *Pg*, papillary layer of gum; *Co*, cortical bone of alveolus or socket; *M*, spaces of bone.

The stomach has four coats: an outside smooth coat, a second muscular coat which enables the stomach to contract and expand, an inner much-folded coat of mucous membrane, and one between this and the muscular coat,

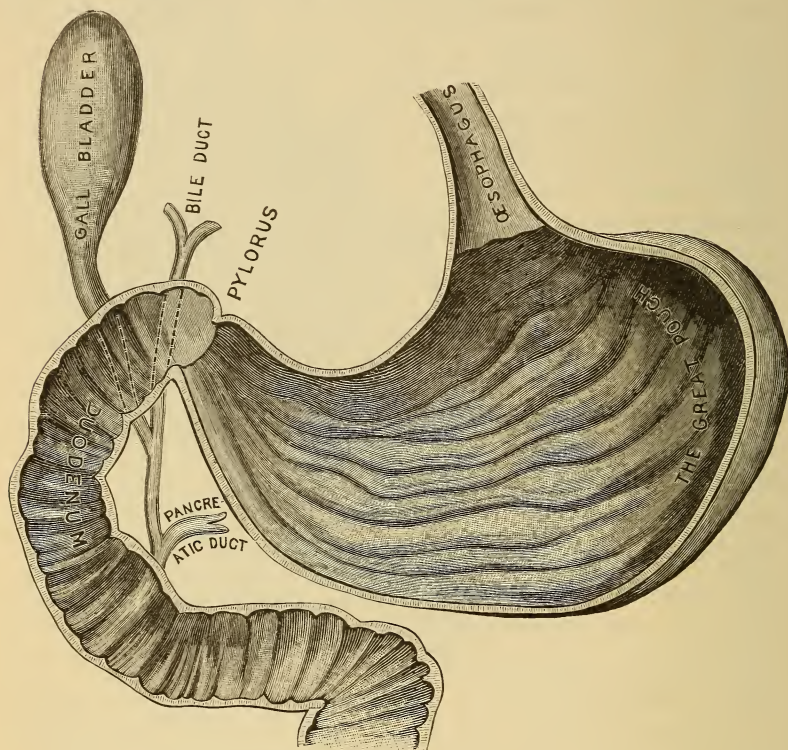


FIG. 25. — Inside of the stomach, front view, showing the folds (or rugae) of the mucous membrane.

which is called the *sub mucosa*. In the muscular coat the muscles run both lengthwise and crosswise, and by contracting first one set and then another of these muscular coats give the stomach a churning motion.

The inner mucous coat is thrown up in folds when the

stomach is empty, but these are flattened out when the stomach is full.

The *gastric glands* are situated in the mucous lining and pour out the gastric juice when food enters the stomach, or when it is in the habit of receiving food (Fig. 26).

The *pancreas* is a long spongy organ which secretes the pancreatic juice and empties it into the *duodenum* near its union with the stomach. The *small intestine* has, like the stomach, four coats, but the inner one, in addition to folds similar to those which we noticed in the stomach lining, is also pushed up into little fingerlike projections called *villi*, which very much increase the inner surface of the intestine. The food gets into the hollows between the villi and is in this way kept from passing so quickly through; meanwhile the villi can absorb the digested material.

The other intestinal juices are secreted by the intestinal glands which lie between the bases of the villi, and as the food is forced along by the peristaltic action of the intestine, it becomes digested and is absorbed by the villi (study Figure 27).

The large intestine is about five feet in length. There is little nourishment left in the food when it reaches the large intestine, so that it consists of refuse and water. This latter is absorbed as it passes along, and the refuse is carried away.

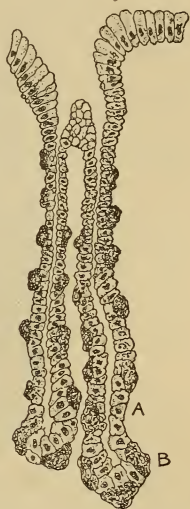


FIG. 26. — A peptic gland, from cardiac end of stomach. Very much magnified. A, central or chief cells, which make pepsin; B, border or parietal cells, which make acid. [From Miller's *Histology*.]

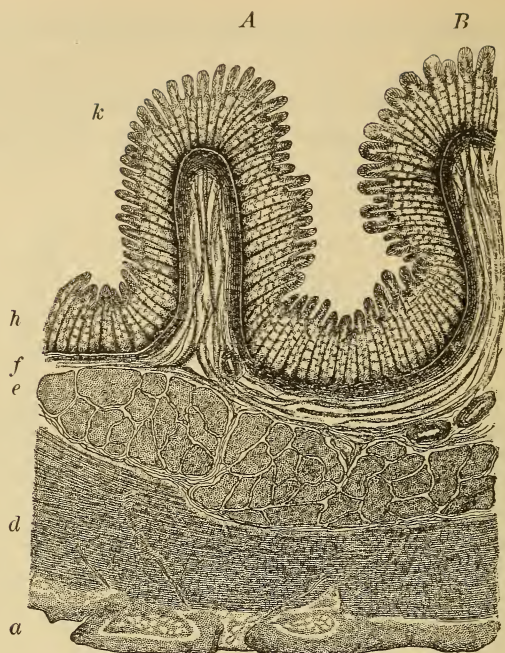


FIG. 27. — A very much magnified picture of a slice through the small intestine. [Benda.] Notice the outer strong coat of connective tissue (*a*), the muscular coat (*d* lengthwise, and *e* circular), the submucous coat of connective tissue (*f*). The mucous membrane (*h*) with two very large folds (*A* and *B*) which run crosswise around the inside of the intestine. (See duodenum, Fig. 25.) Notice the fingerlike projections (*k*) which cover the whole surface of the mucous membrane, and are so fine and delicate that the surface of the membrane looks and feels like velvet. Between the fingerlike projections or villi there are little glands dipping down into the mucous membrane. These intestinal glands are similar to the stomach glands except that they have no border cells. (See Fig. 26.)

8. REVIEW OF ANATOMY OF DIGESTIVE SYSTEM

1. Name the parts of the alimentary canal, beginning with the mouth.
2. Name the glands which form a part of the digestive system.

3. Draw a diagram of the digestive system.
4. How many teeth have you? How many, if any, belong to the temporary set? How many teeth will be required to complete your permanent set, and when ought they to appear?
5. What provision is made to guide the food on its passage through the pharynx?
6. How can one swallow water when the head is lower than the stomach?
7. How many kinds of tissue in the wall of the stomach? What is the work of each?
8. What is the advantage of the stomach having a lining larger than the outside wall, thus causing the lining to be thrown into folds?
9. What is the advantage of the crosswise folds of the mucous membrane lining the small intestine?
10. What are the villi? What are the intestinal glands?
11. Of what use is the vermiform appendix? How did man come to have such an organ? How large is the rabbit's vermiform appendix? Is this organ useful to the rabbit? Could man live without it?

9. DIGESTION BY SALIVA

WE called plant digestion the process of changing food from a form in which it cannot be used to a form in which it can be used, and the same definition will do for animal digestion.

Plant digestion is, however, carried on outside of the plant body, while animal digestion goes on within the animal body. The process of animal digestion is so thoroughly understood that it can be imitated outside of the body, and the process watched.

We found that plants cannot use starch until it has been changed by a ferment. The same is true for animals; and as the process goes on within the body, the mouth is supplied with a juice called saliva, which produces this change. Starch can be acted upon by the saliva much more readily after it is cooked, so that all cereal foods, potatoes, and other starchy vegetables, are always cooked before being eaten.

When the food has been prepared, it is taken into the mouth and masticated. This process of mastication has two purposes: first, to grind it into small particles that can be reached by the saliva; and second, to moisten it thoroughly, so that it may be more easily swallowed, and so that it will have enough of the saliva to make the change.

It is interesting to watch the process of digestion, and to find out just what the change is. Suppose we put into a glass tube a little cooked starch, some saliva, a little water, and then, after shaking it up, hold it in the warm hand for a few minutes. Now, if we put a few drops of iodine in the tube, we shall find no blue color, which proves there is no starch, but a purple color, which iodine always shows in the presence of dextrine, or half digested starch. We could go on and show that there is actually sugar present, after five minutes of warmth upon the saliva and starch. Saliva, then, is a juice whose work is to change starch to sugar.

EXPERIMENTS

1. Prepare starch paste by rubbing starch in water to a thin creamy consistency, and boiling until it is clear.
2. Put into a test tube one fourth teaspoonful of starch paste, a little saliva, and an equal amount of water; shake

up the mixture, and hold it in the hand for a few minutes to keep it warm. Add iodine, and instead of the blue color of the starch, we get a reddish blue color, showing that the starch has been changed (to dextrine).

3. Mix in a test tube, as before, starch paste, saliva, and water. Keep warm five minutes. Add an equal volume of Fehling's Solution, and heat to boiling. The precipitation of copper proves that sugar is present (maltose).

4. Try these experiments with raw starch, and show that saliva digests cooked starch much more readily than it digests raw starch.

10. DIGESTION BY THE GASTRIC JUICE

WE found the saliva of the mouth to act upon the starchy foods, changing them to sugar. But as saliva has no effect upon proteid foods, nature has supplied another juice in the stomach to do this work.

The food, when it is swallowed, takes down into the stomach a quantity of saliva which carries on the starch digestion. The gastric juice of the stomach does not begin to flow until after the stomach is stimulated by the presence of food; and, as it collects slowly, it gives the saliva time to go on with its work on the starchy foods.

If we test the saliva, we find it alkaline, that is, like soda; but if we test gastric juice, we find it acid. You know when we put sour milk and soda together, one counteracts the other. This is true of any alkali and acid. After enough of the acid gastric juice has collected to neutralize the alkaline saliva, the latter can no longer do any work. Then the gastric juice begins its work upon the proteids.

During the half or three quarters of an hour in which the saliva can work before the gastric juice has made the

stomach too acid, only a small portion of the starchy foods has been digested ; the rest passes on into the intestines.

If the food has been well cooked and thoroughly masticated, so that the gastric juice can get at every particle, the work goes on faster, and with greater ease.

When we eat sugar, we are relieving the saliva of its work by eating food already changed ; and when we eat peptonized foods, digested proteid food, or peptone, we are relieving the gastric juice of its labor.

The gastric juice is secreted by the gastric glands (Fig. 26). These are in the mucous membrane of the stomach. Those at the cardiac end of the stomach differ from those in the pyloric end in having *border cells* which secrete acid. The gastric juice contains both acid and pepsin.

EXPERIMENTS

Get a pig's stomach from the stockyards, or from the village slaughterhouse. The stomach of a pig is very similar in size and structure to that of a man. Cut it open, rinse it off, and make a careful study of the coats, and of the mucous membrane. Draw figures, and make a full description in your notebook.

2. With an old table knife or a strong spoon scrape the mucous membrane of the stomach, saving the slimy scrapings in a pint jar. Add water enough nearly to fill the jar, stir or shake vigorously for several minutes, add the juice of a lemon to take the place of the acid which the gastric glands of the stomach usually secrete. Label this : *Gastric Secretion*.

3. Buy five cents worth of pepsin from the druggist, put it into a pint jar, add the juice of a lemon, and fill the jar with water ; shake thoroughly, and label : *Artificial Gastric Juice*.

4. Cut or tear off some fine stringlike shreds from a piece of raw steak. Put two or three of these into a test tube with the artificial gastric juice and keep warm for fifteen minutes, noting very carefully all changes. Repeat with gastric secretion.

5. Digest very soft-boiled egg with the two different preparations of gastric juice.

6. Try starch paste and a piece of fat to see if gastric juice will digest either.

11. DIGESTION BY THE PANCREATIC JUICE

PERHAPS you have wondered what became of all the starch which the saliva did not digest, and when you know that gastric juice digests only a part of the proteid, and that as yet there has been no effect upon the fats, you will see clearly the need for another digestive fluid.

When the food leaves the stomach it consists of the still undigested starch, the still undigested proteid, the fats, such sugar as we may have eaten, mineral matter, and water, besides the dextrine and sugar and peptone which have been formed by the saliva and the gastric juice. These all mixed together make a grayish, soupy mixture, which we call chyme. The chyme leaves the stomach and enters the duodenum, the upmost section of the intestine. Just at the entrance of the intestine is a tube from which the pancreatic juice enters the duodenum, and this juice, with the help of the intestinal juice and the bile, continues the process of digestion.

The pancreatic juice has three kinds of ferments, each of which has its own particular work. One ferment acts upon starch, changing it to sugar ; one acts upon proteid,

changing it to peptone ; and one changes fat into an emulsion, or into soap, which may readily be absorbed from the intestine.

The intestinal juice is secreted by the little intestinal glands that are located in the mucous membrane of the small intestine, between the bases of the villi. This juice contains one ferment which has the power of changing such sugars as maltose, lactose, and cane sugar to grape sugar, or dextrose.

The bile is secreted by the liver, and assists the pancreatic juice in making an emulsion of the fats and oils. The bile contains no ferment. The mucus which it contains in abundance lubricates the wall of the intestine, and so helps the food to slide along through the narrow canal.

The combined effect of these digestive juices is quickly noticed on the still undigested food, which is soon in a condition to be used in the body as nourishment. In other words, the food is now digested.

EXPERIMENTS

1. Buy from the druggist five cents' worth of *Pancreatin* ; put it into a pint jar ; add one quarter teaspoonful of baking soda (bicarbonate of soda) ; nearly fill the jar with water and shake vigorously. Label : *Artificial Pancreatic Juice*.

2. Put into a test tube a few shreds of raw steak or a bit of soft-boiled egg, add a half tube of the pancreatic juice, and see if it will digest either of these in fifteen to thirty minutes.

3. Put into a test tube a little starch paste, add half a tube of pancreatic juice, shake thoroughly, and keep

warm fifteen minutes. (a) Take out half of the mixture and test with iodine to see if the starch has been partly or wholly changed to dextrine. (b) Take the other half of the mixture; add an equal volume of Fehling's Solution; shake to mix; heat to a boiling temperature and note if any of the starch has been changed to sugar (maltose).

4. Add to a spoonful of olive oil an equal volume of Artificial Pancreatic Juice; shake vigorously two minutes; note that the oil is changed to a white, milky liquid, an emulsion containing some soap.

Note that some preparations of pancreatin will digest proteid and fat; some will digest starch and fat; while a perfect preparation digests *proteid*, *fat*, and *starch*.

12. REVIEW OF THE WHOLE PROCESS OF DIGESTION

1. How many digestive juices are there? Where are they made or secreted? In what part of the alimentary canal do they do their part of the digestion?

2. How many different kinds of food do we eat? Where is each kind digested?

3. What is *chyme*, and of what does it consist?

4. How many ferments are at work in the small intestine? What is the work of each ferment? Into what final form is starch changed? Proteid? Fat? Cane sugar and milk sugar?

5. Why do the contents of the small intestine look like milk?

6. What is the test for starch? For dextrine?

7. What is the test for sugar (dextrose, maltose, lactose)? What is the reddish substance which separates out in the test?

8. What is the name of the ferment of the stomach?

13. THE HYGIENE OF DIGESTION

Now that we know the elements of food, and what value each has in the building up of the tissues, we are ready to decide the best method of preparing foods, the best time for eating them, and some other points regarding food and health.

In tasting a raw potato or raw rice, we noticed the granular feeling of the starch and the unpleasant taste. If we were to try to digest raw starch in a little saliva we should find it still undigested after fifteen or twenty minutes, while the cooked starch and saliva show dextrine after one minute. The cooking breaks up the starch grains and allows the saliva and pancreatic juice to reach the starch itself and digest it.

Therefore, *all starchy foods should be thoroughly cooked*. It does not follow that all other kinds of food should be much cooked. For example, raw egg digests very quickly, while egg that has been cooked becomes hard and so compact that the gastric and pancreatic juices cannot readily penetrate them to digest them.

Meat which contains much connective tissue must be cooked for a long time at a temperature just below boiling, that the connective tissue may be rendered in part digestible; but as a rule, lean meat should be cooked only enough to make it palatable.

There is much talk about the use of meat, and perhaps it will be well to say that the people who have done the most toward the advancement of civilization have been the *meat and vegetable eating* people and *not the vegetarians*. Although the proteids can be obtained from vegetables, there seems to be something else which meat alone can give. The fault then is not in eating meat at

all, but in eating it too often and in too great quantities. One needs more meat in winter than in summer. English and American people eat too much meat. A proper amount of meat makes one active, while too much makes one nervous. People engaged in severe bodily exercise can eat much more meat without affecting the nerves than can be eaten by students or people engaged in less active labor.

We have seen that starch is an important part of our diet and that before we can use it in building up tissue it must become sugar. The question naturally follows, why do people often say we should not eat sugar nor candy? Perhaps it will help us to find out if we remember how many of the foods we eat contain starch, which will, of course, make sugar; and if we also remember that sugar is not a muscle making, but a heat making food. Sugar and candy are nourishing, but if we eat much of them we add too much sugar to our diet and make our stomachs liable to fermentation.

Then again, such things would do little if any harm to the average person if eaten at the end of a meal, and thus taken at a proper eating time. But they are seldom taken then, and one of the most injurious things we can do is to eat at irregular hours. Why? Because if we are regular in our meal times, the digestive juices become regular in the time that they appear in the stomach and intestine, and at the usual time for eating they will flow freely to do their work.

If between the meals we take any kind of food, it stimulates the juices to flow, and then when we need them for the regular meal, which is heavier and needs more of the juices, they do not flow readily, and the food is not well digested.

14. THE HYGIENE OF DIGESTION (*continued*)

HAVING now properly chosen our food and cooked it in the best manner, we are ready to decide when it should be eaten. Certain people tell us to eat no breakfast, others to eat no lunch and still others to eat nothing just before sleeping; but all of these things do not touch upon the fundamental rule of eating, which is : *Eat only so much as is needed for nourishment, and eat only at regular hours.*

One of the most frequent causes of overeating is the practice of serving too many things at one meal. In order to eat a little of each thing presented, more is eaten than otherwise would be. This is only one of the drawbacks of the practice of serving a great variety at one meal. When so many things are served at one meal the possible number of things is much sooner used up, and one becomes tired of his food, or, as we say, he loses his appetite. There is also the added expense in money, time, and labor entailed by the addition of unnecessary things.

Meat is one of the most common articles of diet and we have found that it is rich in proteid. It has been found that the nations which use meat are the best thinkers and the most progressive people. It has also been learned that the people who eat the most meat, the English and Americans, are most subject to such diseases as gout, neuralgia, and rheumatism. Meat gives no food material which cannot be obtained from vegetables, and yet the eating of meat seems to give an activity and agility that vegetable food does not impart. When meat is eaten in large quantities this activity increases until the person becomes nervous, restless, and irritable.

Those who are doing heavy manual labor can eat much more meat without receiving harm than can be eaten

by less active people. Those who have rheumatic tendencies should avoid the use of lean meat except in small quantities.

Rich pies, cakes, and puddings you will perhaps think are useful because they contain sugar, eggs, milk, fat, and flour, all of which are nourishing, but unfortunately they are so put together as to make them very hard to digest, and this makes the time required for digestion longer.

The main thought in the hygiene of digestion is : *Eat those things which are for our bodily good, although they may not be the most pleasing to the taste ; and avoid those things which do us harm, although they are most to our liking.* EAT TO LIVE, *not* LIVE TO EAT.

15. THE HYGIENE OF DIGESTION — WATER

IN the little corn plant that grew from the seed because of the warmth and moisture it had, we found nine parts out of ten to be water. In all plants, from the least to the greatest, we find a large quantity of water.

Water is nature's drink, intended for all life. It exists in the greatest abundance, and all living things are able to procure it. Rivers, lakes, and springs are nature's reservoirs for storing pure water. Wells and cisterns are man's reservoirs.

The purest water is that taken from nature's reservoirs where they are not near large cities. When the city refuse empties into a body of water it leaves many impurities and germs of disease. The water must then be taken from far beyond the reach of the impurity or it must be boiled to kill the germs. Rain water is the purest form of water aside from those just mentioned, provided it has not become impure after falling.

The artesian well is the most artificial plan of procuring water, and water from such wells is often heavily charged with mineral salts that are not the best for our use. The system is unable to take up and use lime and magnesium salts in this form. They therefore tend to clog the system, causing a tendency to constipation, or if absorbed entail very hard work upon the kidneys to throw them out of the system. This water is more healthful if boiled; or better yet if distilled.

Sugar and salt must have water to dissolve and dilute them before they can be absorbed by the body, hence the desire for drink after eating them.

All processes of digestion require water to complete them. It is, however, not a good practice to wash food down with water. Let the saliva moisten the food, and let the water be taken, a little at a time, when the mouth is empty.

It is beneficial to take water with the meals and after the meals, but it is not so well to drink it just before the meal. If ice water is used it should not be taken by the half glass but should be *sipped*, that it may be warmed before reaching the stomach.

After what has been said of the harmfulness of the lime and magnesium minerals in the water, the question would naturally follow, why then do we use mineral water? These mineral waters which are used as beverages contain other minerals than lime and magnesium, and have a special medicinal value. Effervescent mineral waters contain carbon dioxide under pressure. When the pressure is removed the gas begins to expand and escape, causing the bubbling. The salts of most mineral waters stimulate the excretory organs, and are usually taken for this purpose.

16. THE HYGIENE OF DIGESTION — DRINKS

I. REFRESHING DRINKS

UNDER this heading we may mention first *lemonade and other fruit acid drinks*, which are so pleasing to the taste in the summer, and really aid in the digestion if taken at the right time. The gastric juice of the stomach is acid, and will flow freely upon the entrance of food into the stomach. But if just before the food is taken we introduce an acid into the stomach, the gastric juice will not flow so freely, and the food is hindered in its digestion. If the fruit acid comes in during the latter part of the meal, after the gastric juice has already flowed, it assists in the digestion. Fruit acid drinks are then better not taken just before or during the early part of the meal.

Fruit Juices, such as apple juice or grape juice or raspberry juice, may be extracted, mixed with a little sugar, boiled to kill all germs, and then bottled to prevent fermentation. These with the addition of a little water also make refreshing drinks.

Fruit Sirups are fruit juices cooked with enough sugar to keep them from fermenting without sealing. These must be used with a great deal of water, in order to make refreshing drinks. They are more often used as flavorings for other drinks.

Soda water, without flavoring, is simply water and carbon dioxide, and derives its name from the soda which was originally used in making the carbon dioxide. In this form it may be classed with refreshing drinks; when ice cream, milk, or eggs are added, it should rather be classed with the next group. Soda water is usually flavored with a fruit syrup.

II. NOURISHING DRINKS

Nourishing drinks, including milk, cocoa, chocolate, and the cereal drinks, such as "postum cereal" and "grano," possess a food value in themselves, and when they are served with cream and sugar become still more nourishing.

All of these drinks are best taken with the meals, or when food is required, as they demand the work of all the digestive juices to digest them.

III. STIMULATING DRINKS

The *stimulating drinks*, which have no other important properties, are coffee and tea.

Tea contains tannin, which gives the dark color to the tea, and hinders the digestion. Neither tea nor coffee possesses any nourishing properties, except for the sugar and cream that are taken with them.

17. THE HYGIENE OF DIGESTION—ALCOHOLIC DRINKS

I. IS ALCOHOL A FOOD?

EXPERIMENTS have recently been made by Professor Atwater, of the government Department of Agriculture, in which new proof of the oxidation of alcohol in the body was collected. This has opened again the old question as to whether, because of its oxidation in the body, alcohol may be classified as a food.

We know that foods yield their energy by oxidation, either after having been built up into living protoplasm or after having been absorbed by the living protoplasm and taken into the cells, though the food is not necessarily

built up into living protoplasm before the oxidation can take place.

When it was found out, a good many years ago, that alcohol is nearly all oxidized in the body, the question was at once asked, "Is not alcohol then a food?"

Investigations were made, and the question was debated with the result that alcohol continued to be classified with the poisons, and not with the foods.

The question has been opened several times during the last fifty years, but always with the same result. Scientific men, generally, continue to classify alcohol as a poison, and not as a food.

Morphine is oxidized in the body, and yields its energy to the body, yet every one recognizes morphine as a dangerous poison, though it is often given by physicians with benefit in cases of illness.

So we see that a substance cannot safely be used as a food simply because it is oxidized in the body.

A food is a substance whose nature it is, when absorbed into the blood, to nourish the body without injuring it.

When we say that beef is a food, everybody understands that we mean beef that has been cared for in the usual way. If lean meat is exposed to a warm atmosphere for a number of days, a change takes place, caused by the growth, within the meat, of millions of bacteria. The bacteria themselves would not hurt one if they were killed by cooking, but some of the waste matter (ptomaines) thrown out by the bacteria would not be made harmless by cooking, and might seriously poison any one eating the meat. This process of decomposition of meat is a fermentation, or putrefaction, and the bacteria are called organized or living ferments.

In a similar way sugar, in a dilute solution in water, if

exposed to a warm atmosphere, will undergo a fermentation, caused by the growth, within the solution, of millions of yeast plants, which are organized or living ferments. The yeast plants themselves would not hurt one, but some of the waste matter thrown out by the plant would not be made harmless by heating, and if kept from passing off by evaporation might seriously poison any one drinking the solution.

It is the nature of meat and sugar, when absorbed into the blood, to nourish the body without injuring it; but if ptomaines are formed in the meat, or if alcohol is formed in the sugar solution, the previously wholesome foods become poisonous, owing to the presence of the ptomaines or alcohol.

When we use the word poison, we are likely to think of a substance, such as strychnine or arsenic, that causes or may cause death in a very short time. But there are many poisons that work very slowly, sometimes requiring many years to cause death or a serious disabling of the system. Painters are sometimes affected with *lead poisoning*, due to small quantities of lead absorbed day by day for years. If a man were to take a considerable quantity of the poison at once, it might cause death in a few hours or days. Arsenic may be taken in very small doses day after day for many years without causing death, but it is no less a poison because it does its damage slowly.

When alcohol is taken in small quantities, it is oxidized in the system, and gives up its heat energy to the body. This heat will be given off to the body, just the same as heat caused by the oxidation of sugar or bread. But the condition of the body, after it has oxidized alcohol, is quite different from its condition after it has oxidized sugar or bread.

Benzine is very easily oxidized. If it were poured upon the fire of a locomotive, it would make a furious blaze, which would make the water in the boiler heat rapidly, and that, in turn, make the wheels turn more rapidly. But the benzine would burn so rapidly as almost to make an explosion, and a very large part of the heat caused by the oxidation would be lost. The locomotive needs a slow-burning fuel, whose heat can all be utilized. So the body needs such slow-oxidizing substances as sugar, bread, starch, and fat, rather than such a rapidly burning substance as alcohol. The energy of the alcohol is rapidly expended, because the alcohol causes the blood to come to the surface of the body, and the blood cools so rapidly that more heat energy is lost from the body than that contained in the alcohol, thus leaving the temperature of the body lower than it was before the alcohol was taken.

Let us now listen to some of the leading medical men as to whether alcohol may be considered a food.

“Although the relation, just alluded to, between the burning of alcohol and the burning of the nutritious substances in the animal organism, has not been fully explained physiologically, this much is true, that alcohol, taken however moderately, is not to be classed among the nutritious substances.”¹

Dr. McConachie, of Baltimore, says: “Alcohol exerts a pernicious influence on the development and function of the muscular and nervous systems, the special senses and mental activity of those who use it. This is not the rôle played by a true food.”

Dr. A. Forel² says: “Alcohol, or ethyl-alcohol, is a

¹ Adolph Fick, Late Professor of Physiology, University of Wurzburg, Germany.

² Professor of Nervous Diseases in Zurich, Switzerland.

poisonous matter, both for the human and animal organism; its venomousness increases with the amount and frequency of the doses. But even when partaken of in the most temperate way, it plainly interferes with the functions of the various organs; it cannot be regarded as being either nourishing or strengthening; and therefore it is of no use whatever in a normal diet, and cannot be counted as a factor of the same."

"A physicist could experiment with gunpowder and prove that it is easily oxidized and gives rise to a large amount of heat and energy. From this it might be argued that gunpowder is a most useful kind of fuel for cooking-stoves. Such a conclusion would be hardly less logical than the conclusions that have been drawn from these experiments with alcohol, and which regard it as a useful food for the body.

"Gunpowder is a more unsafe fuel because of its secondary effects, and in the same way the food value of alcohol cannot be determined by its power of being oxidized, but must include the consideration of its secondary effects as well."¹

"In order to be a food it is not sufficient that a substance be decomposed (or oxidized) in the tissues. Under these conditions many harmful substances would be considered foods. Ether is decomposed in part, chloroform is partially destroyed. But do we consider these substances foods? Certainly not. Other things than oxidation are necessary to nutrition. It is necessary that the decomposition be made in a way that will not injure the vitality of the cells. A part of the alcohol that is destroyed on the body undergoes this decomposition in a way that is injurious. Observe that whereas true foods,

¹ Professor H. W. Conn, of Wesleyan University.

such as sugar and fat, are destroyed slowly, easily, without provoking too lively a combustion, alcohol is burnt too rapidly, provoking a veritable explosion. Suppose that a locomotive has to run a certain number of kilometers; in order to do this it must be given food. This is the coal, which it burns slowly and methodically. If in the place of coal we throw naphtha on the fire, the combustion of this may furnish as much heat as the coal, but it is burnt instantaneously, in the form of an explosion. The heat thus produced is not utilized in the machine. What naphtha is for the locomotive, alcohol is to our bodies; it is an explosive but not a food.”¹

When put to a practical test on a large scale, as when given to soldiers in severe army work, alcohol fails as a food most conspicuously. “It has been shown over and over again that those who endure the greatest fatigue and exposure are the men who do not drink.”²

II. THE EFFECTS OF ALCOHOL UPON DIGESTION

Professor Kochlakoff, of St. Petersburg, has experimented on five healthy persons, aged from twenty to twenty-four years, with reference to the effects of alcohol upon digestion. Ten minutes before each meal, each person was given three ounces of alcoholic liquor, containing from five to fifty per cent of alcohol, which is about the proportion found in ordinary liquors. The following results were obtained:—

“Under the influence of alcohol, the acidity of the gastric juice and the quantity of hydrochloric acid, as well

¹ Doctor Bienfait, of Liege.

² William B. Rochester, Brigadier General, U.S.A. (Retired).

as the digestive power of the gastric juice, was diminished. This enfeebling of the digestion is especially pronounced in persons unaccustomed to the use of alcohol."

Professor Chittenden and his associates of Yale University have made extensive experiments upon dogs, and have found that, though the presence of alcohol or an alcoholic beverage in the stomach causes a greater amount of gastric juice to be secreted, still the presence of alcohol in the stomach retarded digestion.

The results which Professor Chittenden gives as "strictly comparable," because "they were carried out in succession on the same day," are as follows:—

Number of Experiment.	$\frac{1}{10}$ lb. meat with water.	$\frac{1}{10}$ lb. meat with dilute alcohol.
XVII α 9:15 A.M.	Digested in 3 hours.	Digested in 3:15 hours.
XVII β 3:00 P.M.		
XVIII α 8:30 A.M.	Digested in 2:30 hours.	Digested in 3:00 hours.
XVIII β 2:10 P.M.		
XIX α 9:00 A.M.	Digested in 2:30 hours.	Digested in 3:00 hours.
XIX β 2:30 P.M.		
XX α 9:15 A.M.	Digested in 2:15 hours.	Digested in 2:45 hours.
XX β 2:30 P.M.		
VI α 9:15 A.M.	Digested in 3:15 hours.	Digested in 3:45 hours.
VI β 1:00 P.M.		
Average . .	2:42 hours.	3:09 hours.

From this table of results that may be compared, we see that with alcohol present in the stomach the digestion was retarded twenty-seven minutes in the average result.¹

Nothing could be further removed from the truth than

¹ *American Journal of Physiology*, Vol. I, 202-203.

the popular notion that alcohol, at least in the form of certain wines, is helpful to digestion. Roberts showed, years ago, that alcohol, even in small doses, diminished the activity of the stomach in the digestion of proteids. Gluzinski showed, ten years ago, that alcohol causes an arrest in the secretion of pepsin, and also in its action upon food. Wolff showed that the habitual use of alcohol produces disorder of the stomach to such a degree as to render it incapable of responding to the normal excitation of the food. Hugounence found that all wines, without exception, prevent the action of pepsin upon proteids. The most harmful are those which contain large quantities of alcohol, cream of tartar, or coloring matter. Wines often contain coloring matters which at once completely arrest digestion, such as methylin blue and fuchsin.¹

Blumenau says, "On the whole, alcohol manifests a decidedly unfavorable influence on the course of normal digestion even when taken in small quantities, and injures the normal digestive functions."²

REVIEW OF THE HYGIENE OF DIGESTION

1. Cereals, vegetables, and fruit, with eggs and the dairy products, make a complete and perfect diet, though meat in moderate quantities may be added with advantage.

2. Meat contains, besides proteids and fats, which may be furnished by a vegetable and dairy diet, some substance which seems to stimulate men to higher endeavors. For this reason a moderate amount of meat is desirable.

3. If meat is eaten in too large quantities it makes people nervous and irritable, and more likely to suffer from neuralgia, rheumatism, or gout.

¹ J. H. Kellogg, M.D.

² G. F. Mather, M.D.

4. One may be intemperate in eating. One should eat only as much as is needed for nourishment, and eat at regular hours only. A very good rule to follow is to eat slowly and to stop eating as soon as one is satisfied.

5. *Eat to live, but do not live to eat.*

6. Pure water is nature's drink for plants and all animals, including man.

7. In the warm weather of spring and summer one may drink freely of such *refreshing drinks* as *lemonade* and *other fruit-acid drinks*.

8. *Nourishing drinks*, such as milk, cocoa, chocolate, and the cereal coffees, are liquid foods, and should be taken only at meal times.

9. *Stimulating drinks*, such as tea and coffee, are injurious to children and young people, and if taken in more than moderate quantities, are injurious to grown up people. There is much intemperance in the use of tea and coffee.

10. Some people have claimed that alcohol is a food; but *the leading scientists do not say that it is a food*.

11. Alcohol appears to stimulate at first, but it really lessens the brain control, the self-restraint, and the will power, besides dulling the senses and the sensibilities. Thus *Alcohol is a true narcotic even in small doses*.

12. Scientists classify alcohol as a narcotic poison. It may take years for it to seem to injure the system. The only perfectly safe way to do is to abstain from alcoholic drinks altogether.

18. DOMESTIC ECONOMY

BEFORE we can decide what to buy for our tables, we must decide how much money we have to spend. In mechanical lines of work men earn from \$1.50 to \$4 or \$5 a day, but in the cases where the higher wages are received there is usually a time in the year when work stops, so that an average pay would be about \$2 a day throughout the year, or about \$50 a month. Men in mer-

cantile or professional lines receive salaries varying from \$500 to \$8000 or \$10,000 but a large proportion of men in these lines of work receive about \$1200 per year, so we will consider \$100 a month a fair income.

What are the items of expense for which every one must allow? Rent, clothes, food, and fuel one thinks of at once, but there are other equally important items to consider, such as insurance, savings, benevolence, house furnishings, and incidentals, which includes books, school expenses, and recreations.

Let us suppose these families to consist of three grown people and two children, or two grown people and four children, or four grown people. What proportion of this money shall be given to each item of expense?

Do you think a man can afford to give one fifth of his income for a house in which to live? He certainly cannot afford to pay any more than that; and right here is the mistake most often made—the mistake of allowing too much for rent; because increasing the size of the house increases the amount necessary for help, for fuel, for lighting, and for furnishing, and at once places one in the predicament of living beyond his means. Having then allowed what you think best for this item, it will be well to consider the item of food which must necessarily be a heavy expense, and will consume not far from a fourth of the income in the cases given. Must a man insure his life and must he save for the future? Certainly, he must provide for his family in case of his death, and for himself and family in case he lives beyond his working days. However small the income, this last item should receive something, if possible, and the best way to provide for this is to decide first how much must be saved, and then apportion the rest among the necessary expenses.

The car fares, daily papers, magazines, school expenses, books, and recreations must come under the incidental account; something must be allowed for replenishing the household furnishings, and there must be a fund from which we can draw to help others, to pay our obligations to church and society.

PROBLEMS

1. Let each pupil make out a budget of expenses on a basis of \$100 a month or \$1200 per year. Here are some of the questions which must arise for solution: Taking such a family as that described above, — (a) How much per month shall I pay for rent? (b) How much per month for kitchen and dining room expenses? (c) How much for fuel and lighting? (d) How much for clothing? (e) How much for books, periodicals, and education? (f) How much for works of charity? (g) How much for the church? (h) How much for insurance? (i) How much to be put into the savings bank?

2. How much would your savings account amount to in thirty years at three per cent simple interest?

3. If each \$1000 were withdrawn from the savings bank as soon as so much had accumulated, and put at six per cent interest, to how much would the total savings of thirty years amount?

4. If you were unable to work after the thirty years were passed, what would your annual income be at six per cent on savings, and three per cent dividends on insurance?

5. Make out a budget of expenses for a family of three to come within the limits of income. If the interest and dividends are insufficient, what will you do?

19. DOMESTIC ECONOMY (*continued*)

HAVING disposed so easily of \$100 a month, let us turn to half that sum, which is the average workingman's income, and see how much can be done with that. The family is the same in size, the members of the family are just as hungry, and indeed the father who works with his hands needs more food than does the one who works with his head.

We have decided that the first item to be provided for is *how much for savings?* That should be *not less than one fifth of the earnings* and as much more as the health and self-denial of the family will permit. Then he must carry \$1000 insurance for the benefit of his family. He will then have not more than \$38 to be divided among the other items. As this family cannot have so much money as the one on \$100 per month to spend for food, and must at the same time have as much if not more nourishment, the question is reduced to one of food values — *from what foods can the most energy and nourishment be obtained for the least money.*

Let us see if a family of five persons can live upon \$10 a month for food and still be well nourished. For how much can this family be warmly and comfortably clad? In the selection of clothing on this salary, attention must be given to good wearing qualities and colors that will not fade and look shabby in a short time. Moreover, if the material has good wear in it, when it can no longer be used for the one who first owned it, it will make a warm garment for a smaller member. The ability of the mother to do her sewing in a neat manner, the careful saving of buttons to serve upon one garment after having first served upon another; the careful cutting over of

garments for smaller members, in brief, *the prevention of waste* will make the difference here between comfort and discomfort, if but \$10 are allowed each month for clothes.

Now let me ask how much do you think you can spare for cigars and tobacco and for alcoholic drinks? You have already laid out all of your money in necessary things; from which account will you cut off to allow yourselves the indulgence of this appetite which gives you nothing in return? For the man with \$100 a month let us allow three cigars a day at five cents each or one a day at fifteen cents, which is as little as most men who use tobacco indulge in, and we have \$4.50 a month for tobacco. If added to that ten or twenty cents a day be taken off for alcoholic drinks, we must take off from \$3 to \$6 more. Shall we reduce our rent \$4.50 a month and our food from \$3 to \$6, or must we wear less comfortable clothing? If we do not take it from these items, it will reduce our savings to an alarming extent. Besides, if the father of the family takes from \$4.50 to \$7 a month for the gratification of his particular taste, has not the family at large a right to an equal amount? If they are allowed another \$4.50 or \$7 for candy, nuts, soda water, ice cream, and so forth, to be eaten between meals, we must either give up all idea of saving for the future, or we must cut our living expenses down another notch. When we have but \$50 a month and have stretched every dollar to its utmost, where shall we cut off ten cents a day for beer and five cents a day for tobacco, neither of which will add anything to the general comfort, but all of which will take from the general supply?

From an economic standpoint alone, then, we are forced to the conclusion that the use of tobacco or alcoholic drinks by one or two members of a family is a most

foolish and wasteful proceeding. Furthermore, it works a very grave injustice upon the other members of the family.

PROBLEMS

1. Make out an annual budget on the basis of \$50 per month.

2. How much can you save annually?

3. To how much will the savings amount in thirty years?

4. What will the income be after the thirty years are ended and all money earning stops?

5. How much would a man pay out for tobacco in thirty years at fifteen cents per day?

6. How much would a man pay out for drinks in thirty years at fifteen cents per day?

7. Knowing that drinkers are almost universally smokers, how much would the man in problem 6 spend in thirty years for drink and tobacco at thirty cents per day?

8. To how much would these expenditures amount (in 5, 6, and 7) if each accumulated \$1000 were put at interest at six per cent and left to accumulate until the end of the thirty year period?

20. DOMESTIC ECONOMY

THIRTY dollars a month will provide nourishing, attractive food, with some delicacies, for a family of five persons whose income is a hundred dollars a month.

Fifteen dollars a month will provide nourishing, attractive food for a family of five persons whose income is fifty dollars a month.

Food should be chosen with reference to its nourishment, digestibility, cost, and variety.

Meat is the most expensive article of diet, and is usually eaten too freely.

Soups are inexpensive, and with the addition of vegetables or cereals can be made very nourishing.

A variety of vegetables is advisable.

Corn, as sweet corn, hominy, corn meal (which latter can be used in muffins, brown bread, pancakes, mush, puddings, and so forth), is a cheap and nourishing food.

Fried foods should form a very small part of one's diet.

The secret of good living at low rates is to buy food which is nourishing and in form easy to digest; to buy each thing in its season, and to make good use of what is left over.

I. TYPICAL MENUS

Menu on \$30.00 per month basis.

One of the first things to be determined in arranging a menu which must come within a certain monthly limit is to apportion the weekly allowance (\$7.00 on above basis) and then determine how much of the weekly allowance must be expended for such general supplies as butter, flour, milk, sugar, potatoes, lard, coffee, fuel, and so forth. On a \$7.00 per week basis one must allow about \$3.00 per week for these general supplies, something as follows: butter, \$.50; flour, \$.25; milk, \$1.00, sugar, \$.25; potatoes, \$.15; lard, \$.05; coffee, \$.10; fuel, \$.60; incidentals, \$.10.

TYPICAL MENU FOR ONE DAY

Breakfast — Oatmeal (\$.02), sugar and cream, waffles, maple sirup, cereal coffee.

Luncheon — Omelet (\$.10), bread and butter, milk.

Dinner — Pork and beans (\$.12), tomatoes (\$.05), baked potatoes, brown bread and butter (\$.05), baked apples and cream (\$.05).

On a \$50.00 per month income, not more than \$15.00 per month should be allowed for board. That brings one down to \$3.50 per week for a family of five. Of this about \$2.00 per week will be expended for such general supplies as milk, \$.50; flour, \$.35; sugar, \$.25; butter, \$.35; lard, \$.10; cereal coffee, \$.10; potatoes, \$.25; sirup, \$.10; incidentals, \$.10.

TYPICAL MENU FOR ONE DAY

Breakfast — Bacon (\$.05), potatoes, bread and butter, coffee.

Dinner — Beefsteak (round, \$.12), potatoes, bread and butter.

Supper — Cream of onion soup (\$.01), bread and butter.

II. PROBLEMS

1. Get a list of market prices for various staple articles, such as those mentioned under general supplies, also various vegetables, meats, cereal foods, and so forth.

2. Find out from home or from the teacher the amount of the various supplies needed for a meal for five persons.

3. Find the most economical way to choose the various cuts of meat. For example, some cuts, if large enough, will be sufficient for several days if used in made-up dishes like stews and meat pies for the last one or two meals.

4. Make out a complete menu for a week on the basis of \$7.00.

5. Make out a complete menu for a week on the basis of \$3.50.

CHAPTER VI. — CIRCULATION — HOW THE NOURISHMENT IS DISTRIBUTED

1. THE NEED FOR A CIRCULATORY SYSTEM

NEARLY all of our study of physiology up to the present time has been devoted to the study of foods and their preparation, and to the process of the mastication and digestion of foods.

After the food is digested, it is absorbed into the system from the alimentary canal and forms a part of the blood and lymph of the body. This blood and lymph is tissue and cell food. Every cell of the body requires food in order to enable it to do its work, and it requires a particular kind of food. The cells of the body are working for their board and room, that is, for their nourishment and protection. Their protection is accomplished by their being colonized together in the body; their nourishment is provided in a common stock of nutriment carried by the blood. The cells are constantly drawing their supply from this common stock, and the blood is just as constantly being replenished by absorption from the digested foods of the alimentary canal.

The problems which we have to solve in this chapter are, first, what is the composition of the blood, and second, how is the blood distributed to the different cells and tissues.

Let us now consider the general character of the distributing system. Most of you are familiar with the

method which cities and many towns use in distributing water to the different houses. You know that large mains, as they are called, or large tubes run from a central pumping station along the main thoroughfares of a city, giving off from time to time branches which pass along side streets and supply portions of the city not reached by the main channel; finally, every house has its water pipes, and, after entering the house, the pipes subdivide, each branch finally going to a faucet or other terminal fixture. When the faucet is turned, the water will flow with more or less force, and may be utilized for various household purposes, after which it is carried off first in small pipes that converge to one of considerable size, which leaves the building and passes to the street, where it empties into a still larger one.

In a similar way the drainage or sewerage of a whole city is collected in pipes of ever increasing size, and finally carried away from the city in large mains, to be emptied into some lake or river, and finally to the sea. From the sea the water is vaporized, carried in the form of clouds by the wind out over the land, where it falls as rain, and may be again used by a city, perhaps by the same city that used it at first, though it is not likely that any considerable amount of the water so purified ever does actually come back to the same city which once used it; and for this reason the water sewerage of a city cannot be called a circulatory system.

In the animal body we have a striking analogy to a great city: first, in the need of individual cells for liquid and solid; second, in the actual distribution of this through a system of tubes; third, in the collection of refuse matter or sewage of the system into another system of tubes; fourth, the purification of the sewage. If the

purified sewage of a city were returned and pumped through the same channels for the water supply, the analogy would be perfect, because in the animal body the purified blood passes into the pumping station and is at once sent out again through the system of supply tubes. This fact of the blood making the circulation of the body repeatedly, at one time carrying fresh liquid and food, and another time carrying refuse, has caused the whole system of tubes to be called a *circulatory system*.

As the stream of pure blood in its blood vessel, bringing both water and nourishment, enters a tissue, it at once divides into minute tubes called capillaries, which distribute the blood to each part of the tissues. The blood does not actually empty out into the tissues, as is the case in a water tube that empties out from a faucet into a wash bowl, but the wall of the tube being thinner than tissue paper, there is a ready exchange between the pure blood within the capillary and the impure plasma outside, so that by the time the capillary has passed through the tissue, it has given to the tissue much that was pure and has taken up from the tissue much that was impure; joining with many other capillaries, the stream passes out of the tissue charged with the impurities of tissue waste and tissue oxidation.

2. THE BLOOD

FROM what we have learned, it must be clear that the blood is a very complex liquid, because it contains food for every tissue and cell of the body. Some tissues require proteid food, some fats and carbohydrates, while others require mineral food. The blood must also contain all the waste materials. The blood carries not only liquid

food, but gaseous food, the gas being dissolved in the liquid, and not being in the form of bubbles.

You have all seen blood flowing from a cut or from a bleeding nose, and know that it is red. Not all animals have red blood; the oyster and the lobster have white blood; the common earthworm or angleworm has red blood, and all animals that have a backbone have red blood. There is a very great difference between the blood of the angleworm, however, and the blood of a frog. In the angleworm, the red color of the blood is due to a red pigment which is dissolved in the blood, as the red pigment of raspberries or currants is dissolved in a sirup, giving the sirup its red color.

But the blood of vertebrates owes its red color to innumerable red bodies floating in the blood. These red bodies are called corpuscles. A thin film of blood spread upon a glass and looked at under a high power microscope would look like Figure 28. In studying this figure you will notice first that there are two kinds of bodies floating in the liquid, one a smooth, discoidal body, and the other a granular, spherical body. The smaller discoidal bodies are the ones which contain the red pigment, and because of their color they are called *red corpuscles*. The granular, spherical corpuscles are perfect cells composed of protoplasm, and containing one or more nuclei. This

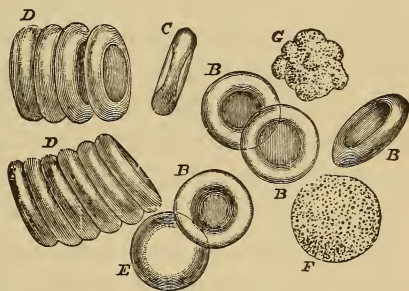


FIG. 28. — Blood corpuscles as they appear under the microscope: *B, C, D, E*, red corpuscles seen in different positions; *F, G*, white corpuscles. Notice that at *D, D*, the red corpuscles have gathered in rouleaux like coins when shaken together.

form of protoplasm generally has the power of contracting, and so these cells have the power of changing shape, like the amœba of which we studied under General Physiology; and because of this power to change their shape they can creep through little pores or openings in the wall of the capillary, and when once free from the capillary they can creep through the pores between the cells of the tissue. These creeping, granular corpuscles are called *white blood corpuscles*.

The red corpuscles are derived from nucleated cells, and may themselves be called modified cells, but they have not the power to change their shape, and all that they do is done passively and not actively; that is, they are acted upon rather than active.

Blood, then, is composed of a nearly colorless fluid called plasma, in which two kinds of cells are floating, the white cells and the red cells, or, as they are more frequently called, the white corpuscles and the red corpuscles. The fluid part of the blood, the plasma, carries the liquid nutriment from the alimentary canal to the tissues. From this we should expect the plasma to contain proteids, carbohydrates, and fats, and so it does. The carbohydrate is the grape sugar, or dextrose, absorbed from the alimentary canal; the fat is in the form of minute globules, while the proteid is in the form of albumen, similar to egg albumen, but much diluted with water. Besides these foods already named, there are water and mineral substances in solution. The minerals are, for the most part, those which are utilized in the building up of tissues. The plasma also contains many waste substances, which are constantly being added to by the tissues and just as constantly being carried away by the excretory organs.

In a similar way the foodstuffs are being added to the plasma by absorption from the alimentary canal, and constantly being taken away from the plasma by the tissues, so that there are in constant progress two additions to the plasma and two subtractions from it ; still, the wonderful adaptation of the system and the delicate control by the nervous system result in keeping the plasma in nearly the same condition, varying more in the relative amount of water than in any other constituent.

The work of the red blood corpuscles is to carry oxygen from the lungs to the tissues ; the work of the white blood corpuscles will be described later.

3. HOW THE BODY IS PROTECTED AGAINST EXCESSIVE BLEEDING

EVERY schoolboy knows that if he cuts his finger deeply the blood will come streaming out ; he knows, too, that the blood will flow only a short time and then stop ; he knows, too, that if the blood is allowed to collect upon the finger, not being rubbed off or rinsed off with water, that in two or three minutes it will form into a jellylike mass upon the finger, and if this jellylike mass is brushed away after the bleeding stops, he will find that the cut is filled with blood which seems to be in the same condition as that which he brushed away.

This is nature's method of stopping the bleeding. The jellylike mass, which forms whenever the blood is exposed to the air after being shed, is called a *cō-ăg' ū-lŭm*, and the process of its formation is called coagulation.

You will remember that in describing milk, when we were studying about foods, the milk separated into small, flakelike coagula on the addition of acid. Each little

mass of the milk would be called a coagulum. You know that if milk is exposed to the warm air for a few hours on a summer's day it will turn into a jellylike mass similar in consistency to the coagulum of the blood. The process which takes place in the milk is similar to the process which takes place in the blood during coagulation.

Sweet milk contains a proteid called caseinogen. When the milk is exposed to the air, a ferment which floats in the air gets into it and causes a fermentation of the milk sugar, which results in the formation of milk acid, and that causes the caseinogen to be separated out in the form of casein.

The blood contains several liquid proteids similar to the white of egg. One of these is called fibrinogen. When the blood is shed, and comes into contact with the air, or any foreign substance, a ferment which is always in the blood, but which does not act when the blood is circulating within the vessels, begins to act upon the fibrinogen, causing it to separate out into stringy fibers. These fibers form a network in whose meshes the red blood corpuscles and the fluid part of the blood are caught.

In some animals the blood coagulates very quickly, and in some animals very slowly. The blood of insects and small birds coagulates almost instantly; human blood coagulates in two to five minutes or more, according to various circumstances. The blood of horses coagulates in not less than five minutes. The coagulation is hastened when the blood comes in contact with foreign matter of any kind, and especially with air or with foreign matter at a temperature considerably higher than that of the body. If a deep wound is bleeding so freely as to endanger life from loss of blood, the coagulation can be hastened by binding over the wound absorbent cotton or linen.

If a boy were to lose a tablespoonful of blood he might be quite frightened, thinking that he was bleeding to death, but it has been found out by experiment that about one thirteenth of the weight of the body is blood, so that any person weighing ninety-one pounds would have nearly a gallon of blood, and at least one third of this or more than a quart could be lost without in any way endangering the life of the person.

If a large blood vessel were cut, the blood might flow too rapidly to be stopped by coagulation alone, so that unless some prompt measures be taken a person might bleed to death in a few minutes. Just what to do in such an emergency will be described later, after we have described the blood vessels.

4. THE ORGANS WHICH CAUSE THE BLOOD TO CIRCULATE

THE HEART

MANY of you have visited the village or city water-works, and have seen the great engine pumping the water through the system of tubes described in a previous lesson. When the pump stops, the water ceases to flow. In a similar way the blood is forced through the system of blood vessels by a pumping organ, the heart. When the heart pumps rapidly the blood flows rapidly, and when the heart pumps slowly the blood flows slowly. If this central pump were to stop its work, the blood would stop flowing. The cells all over the body would be deprived of their proper nourishment and oxygen, and would have to stop working. So we see how important an organ the heart is.

Figure 29 gives the outside view of the heart; this shows the heart as it would look if we could look into the chest of another, and see the heart lying there so that what is on the right side in the picture (Fig. 29) would represent the left side in the body.

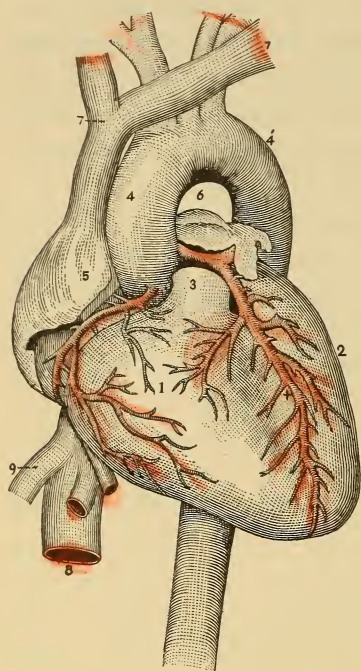


FIG. 29. — The heart and large blood vessels, in front. 1, right ventricle; 2, left ventricle; 3, pulmonary artery, cut short; 4, 4', 4'', aorta, or chief artery; 5, 6, parts of the right and left auricle; 7, 7, veins uniting to form the superior (upper) vena cava; 8, inferior vena cava; 9, vein from liver; +, arteries nourishing the heart.

Notice that the upper left-hand portion of the heart is a little earlike appendage; this is called the left auricle (left ear). There is a much larger chamber at the upper right-hand part of the heart which is called the right auricle.

These auricles are filling chambers for the heart, which hold the blood while the pumping chambers of the heart are forcing the blood into the arteries. These pumping chambers are two in number. They make up the main body of the heart. One of the chambers is directly under the left auricle, and is called the left ventricle,

while the chamber under the right auricle is called the right ventricle.

The general relation of these chambers of the heart can best be shown by a diagram (see Fig. 30).

Notice that the blood enters the left auricle through vessels from the lungs (pulmonary veins); that it passes from the left auricle into the left ventricle through the bicuspid valve; when the left ventricle contracts and forces the blood back against the bicuspid valve, the valve closes, and the blood cannot get back into the auricle, but it can pass out into the aorta, and from the aorta, which is the largest artery of the body, the blood is distributed all over the body, coming back to the heart from the veins, and entering the right auricle. From the right auricle it can pass through the tricuspid valve into the right ventricle, and when this ventricle contracts, the cusps of the tricuspid valve are forced together and closed, while the valve into the pulmonary artery is forced open.

The impure blood passes out to the lungs to be purified, and after purification it returns through the pulmonary veins already referred to into the left auricle.

The left side of the heart has to force the blood all over the system, while the right side of the heart has only to force the blood into the lungs which lie all about the heart in the thorax. For this reason the left side of the heart has a very heavy muscular wall, while the right side of the heart has a much thinner one.

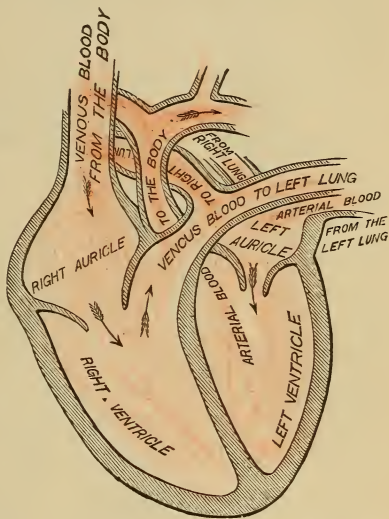


FIG. 30. — Diagram illustrating the course of the blood through the heart. [Tracy.]

5. THE ORGANS WHICH CAUSE THE BLOOD TO CIRCULATE (*continued*)

THE ARTERIES

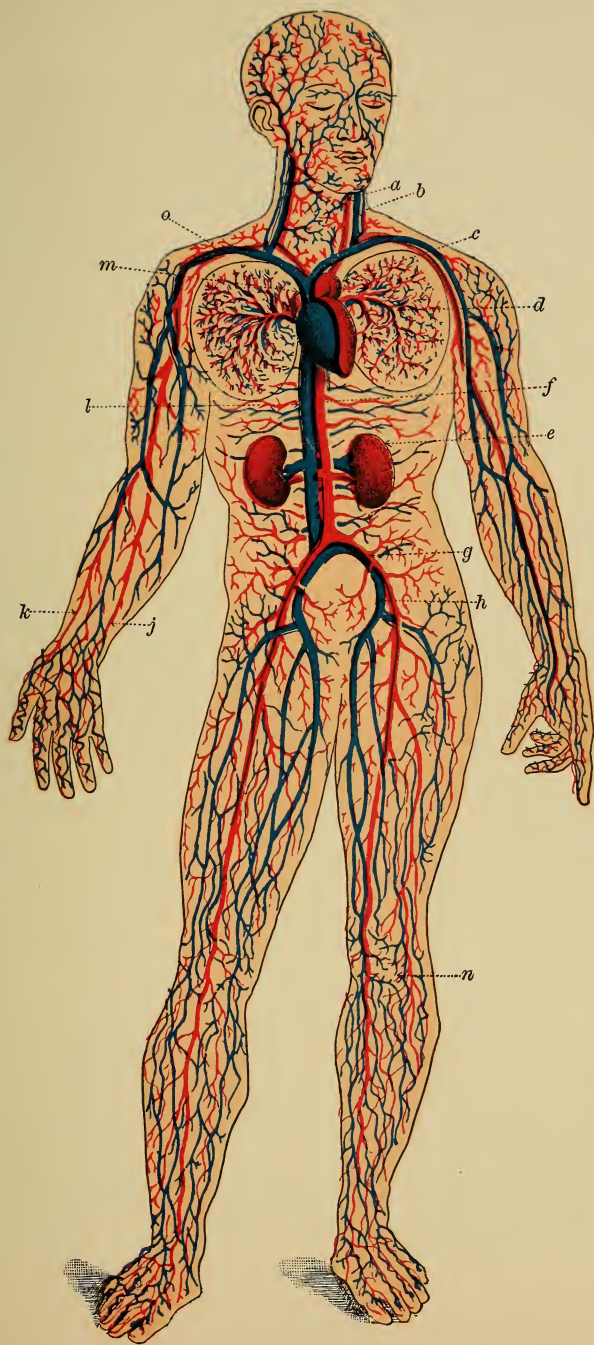
THE tubes which conduct the water from the pumping system of the city to the various houses are composed of either stoneware or iron. The smaller subdivisions within the house which go to the different faucets are metal.

The system of tubes which conduct the blood over the body begins at the heart with a large, thick-walled tube, a little larger than one's thumb. This tube is called the aorta.

All of the tubes which carry blood away from the heart are called arteries. The aorta is the main trunk of this system of tubes. The accompanying plate (page 137) shows the aorta passing upward from the base of the heart, curving around at the base of the neck, and then passing downward along the spinal column. Notice that it gives off branches as it passes downward and therefore becomes smaller and smaller, and divides into two main branches, one passing to each leg.

The larger divisions of the aorta are those which pass to the legs and arms, next in size being those which pass to the kidneys (page 137). These large branches subdivide into numerous smaller branches and twigs, the subdivisions passing outward in every direction, and carrying the blood stream to every portion of every tissue in the body.

When the blood reaches the tissues which it is to nourish, the artery subdivides into branches not larger than a needle. These little arteries are called arterioles.



The arterioles finally subdivide into a network of minute hairlike branches called capillaries. Many of the capillaries are so fine that there is room for only one corpuscle to pass along at a time. These capillaries have walls so thin that the blood plasma can ooze through as the blood filters through the tissues.

Several venules coming together form a vein, and one vein emptying into another will form a large venous trunk. Refer to page 137, and notice the venous trunk getting larger and larger as it passes toward the heart, receiving branches from either side. The large vein

which passes up through the abdomen to the right auricle of the heart is the *inferior vena cava*; the one which comes down from the head and arms, emptying into the right auricle, is the *superior vena cava*.

It has been mentioned above that the wall of the aorta is very thick and strong. It is composed mostly of very dense, strong, elastic fibers of connective tissue, but there are some muscular fibers in the outer portion of the wall of the aorta, and the wall is lined with a very thin membrane, thinner than tissue paper, composed of little platelike cells lying side by side, as shown in Figure 31.

FIG. 31.—Lining of an artery or vein.
[Schaefer.]



The smaller arteries have a much thinner wall, which is composed largely of muscular tissue with only a little of the elastic connective tissue; the lining is the same as that of the aorta.

As we pass to the finer twigs of the arterial system, we find the muscular coat and the elastic coat becoming

thinner and thinner ; finally in the capillaries only the inner coat remains, and, as has been stated above, this coat is so thin and delicate that the blood plasma can ooze through it as the blood is forced by the heart through the capillary network. (Study Figure 32.)

The walls of the veins, although they are much thinner than those of the arteries, are made in the same way. That is, they are made of elastic connective tissue, muscular tissue, and the thin inside lining. The veins have something which the arteries do not have, and do not need ; *the veins have valves*. These valves are so arranged that they open toward the heart.

Thus they allow the blood to flow toward the heart, but do not allow it to flow back. If anything presses upon a vein, the blood may be hindered from continuing its flow toward the heart, but it cannot be pushed back into the capillaries.

There are none of these valves in the veins of the neck and face, because they are not needed there in the usual positions of the body.

When the body is inverted, as when one hangs with his head downward, the blood backs up or flows back into the venules and capillaries of the face and neck, making the skin flushed and almost purplish, if one keeps the position for some time.

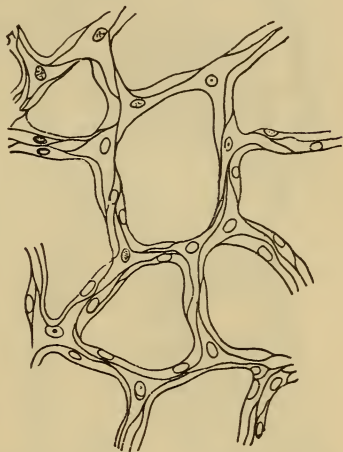


FIG. 32. — Capillary network showing how the walls are made of thin plate-cells. [Schaefer.]

6. THE CIRCULATION OF THE BLOOD

THE blood cannot circulate by any force of its own, but it is forced through the arterial system, the capillaries, and the veins by the pumping of the heart. If you will refer to Figure 33 you will find a diagram of the circulation; the lighter portion represents the arterial system, the darker portion the venous system.

This diagram represents what are called the greater and lesser circulations. The greater circulation is that which supplies the whole body with blood, beginning with the aorta with its numerous branches distributed throughout the system, and ending with the venæ cavæ which bring the blood back to the right auricle.

Notice in the diagram that from the right ventricle the dark stream passes upward to

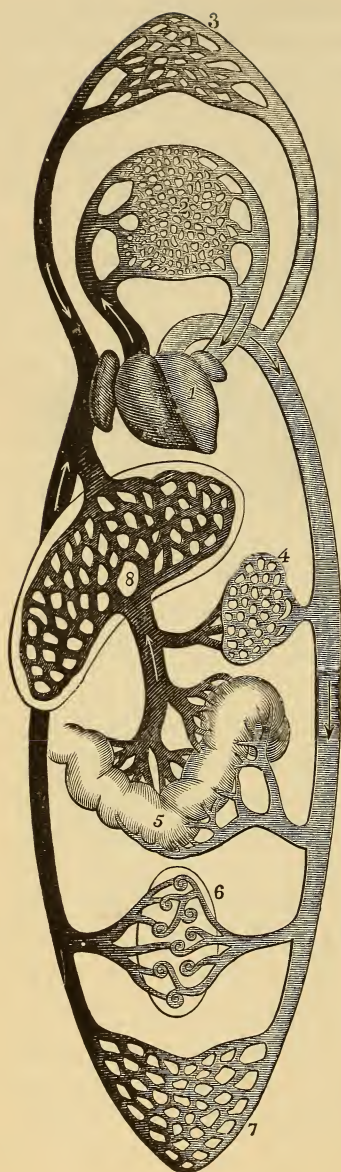


FIG. 33.—Diagram of the circulation. 1, heart; 2, lungs; 3, head and upper extremities; 4, spleen; 5, intestine; 6, kidneys; 7, lower extremities; 8, liver. [Dalton.]

the lungs. This stream is the pulmonary artery, carrying impure blood from the heart to the lungs, where it is oxygenated, after which it passes back to the left auricle through the pulmonary veins. This portion of the general circulation which carries the blood to and from the lungs is called the lesser circulation, or the lung circulation.

Let us now follow the circulation in detail, beginning with the left auricle. Turn back to Figure 30 and notice that the blood flows into the left auricle from four pulmonary veins; from the left auricle it passes through the bicuspid valve into the left ventricle. It passes into the left ventricle because the muscular walls of the left auricle contract and force it into the left ventricle. It does not require much force at first, because the left ventricle is empty; all the force required is enough to swell out its walls. After the auricle has emptied itself into the left ventricle, the ventricle begins to contract. Its contraction presses the blood up toward the base of the heart. This forces the valve together, thus closing the opening into the left auricle, so that no blood can get back that way. The ventricle keeps on contracting until the pressure against the valves into the aorta is sufficient to push them open and force the blood that was in the left ventricle out into the aorta. After the ventricle has emptied itself into the aorta and relaxes, the valves of the aorta clap together and hold the blood in the aorta while the ventricle is being filled again from the auricle. The contraction of the ventricle which throws the blood into the aorta is called the systole.

Now turn to Figure 33; follow the blood from the left auricle into the left ventricle (marked 1) and from the left ventricle around the curve of the aorta. The diagram shows a large branch turning upward to the head and

arms. This branch in the diagram really represents several different arteries, so that the diagram is intended to represent only the general features of the circulation. After giving off blood for the head and arms, the aorta turns downward through the thorax and abdomen, giving off many small branches that run between the ribs and a large one to the spleen (Fig. 33, 4), then there are large branches to the stomach and intestines (Fig. 33, 5), then branches to the kidneys (Fig. 33, 6), and, finally, branches to the legs (Fig. 33, 7).

In all of these different organs to which the blood is supplied, it filters slowly through the capillary network and collects in venous branches corresponding to the arterial branches. Notice that the blood from the spleen, stomach, and intestines collects into a large venous trunk (marked by the white arrow), and passes to the liver (Fig. 33, 8). This is the portal vein. All the venous blood finally collects in the right auricle, whence it passes into the right ventricle (see also Fig. 30); the right ventricle contracts at the same time that the left ventricle does, and sends the blood through the pulmonary artery to the lungs (Fig. 33, 2), where it is oxygenated, after which it passes to the left auricle, thus completing the circulation.

The blood flows very rapidly in the aorta and the large arteries, but as it reaches the tissues and passes into the innumerable small branches the flow becomes very slow, thus giving a good chance for an exchange to occur between the blood circulating in the capillaries and the cells which border the capillaries. As the blood collects again in the venules and veins it begins to flow faster, and continues to increase in its rate of flow until it reaches the heart.

6. THE CIRCULATION OF THE BLOOD (*continued*)

I. THE PULSE

If you put the tips of the fingers upon the wrist near the base of the thumb, you will feel a little throbbing. This throbbing is called the pulse. All the arteries throb or pulsate, but the pulsation of only those larger arteries which are located near the surface can be felt. If one puts the tips of his fingers just in front of his ear, he can feel the pulsation of an artery. A pulsation may also be felt on the side of the neck.

What causes the pulse? When the heart contracts, it throws about half a tumbler full of blood into the aorta; this forces the elastic walls of the aorta to quickly stretch, and it starts a wave down the arterial system, a wave which follows all the branches of the arterial system clear to the farthest branches of the arterioles. This wave is called the pulse.

When the physician presses his fingers upon one of these arteries, he can tell by the way it throbs whether the heart is beating rapidly or slowly, whether it is strong or feeble, and whether the smaller arteries are congested or relaxed. So much depends upon the condition of the heart and the circulatory system in general, that it has become customary for the physician to feel the pulse as one of his preliminary tests.

II. PROTECTION AGAINST BLEEDING

The reason that we do not feel the pulse at almost any part of the surface of the body is because most of the larger arteries are located far beneath the skin. These arteries are in the safest portion of the system; if they

were nearer the surface they might easily become wounded in some of the various injuries which the body suffers, such as a cut with a knife, and then the blood would flow so rapidly as to endanger the life of the person. Even with this protection large arteries or veins are sometimes cut.

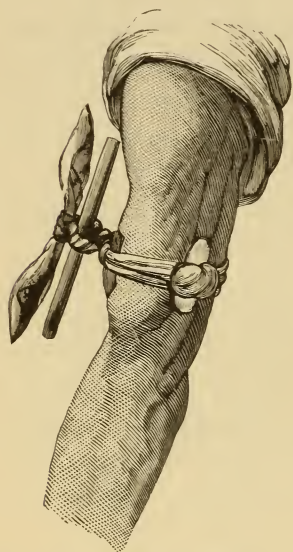


FIG. 34. — Manner of compressing an artery with a handkerchief and stick. [Tracy.]

It is very important for every one to know what it is best to do when that happens. If the vessel is an artery, the blood will come in spurts because of the pulsations. To stop the bleeding of an artery it is necessary to press against the trunk of the artery. This pressure must be between the bleeding end of the artery and the heart.

The best method for making this pressure is to take a handkerchief by its corners, make it into a roll, and tie a single knot in the middle; pass the handkerchief around the limb with the knot above the wound, and tie the ends so that the knot is not tightly drawn; put a stick through (a ruler or a lead pencil might serve the purpose) and then twist the handkerchief tightly enough to stop the bleeding (Figure 34 represents the handkerchief so applied).

III. HOW THE BLOOD NOURISHES THE TISSUES

When the blood reaches the tissues and is slowly filtering through the fine capillaries, some very important

things happen, in fact, the very things for which the whole circulatory system exists.

The plasma of the blood oozes out through the fine pores between the cells of the capillary wall, carrying to the hungry cells which make up the tissue the food which they most need. Some of the fresh plasma passes into the tissue; some of the plasma which was in the tissue



FIG. 35. — Showing how white corpuscles get through the walls of the capillaries. [Hall.]

before, and from which a portion of the nourishment has been taken up by the cells, will pass out of the tissue through the lymph vessels, and, after passing through the lymph circulation, will finally pass back into the blood circulation.

But this is not all that happens while the blood is passing through the capillaries. Figure 35 shows under *A* the way in which the blood corpuscles usually float through a large capillary; under *B* the figure shows what happens when there is something wrong in the cells which

border the capillaries. The white corpuscles leave the center of the stream, pass to the capillary wall, put out a little arm such as shown in cells marked 2 (Fig. 35), force this arm through a little opening in the capillary wall, then gradually creep through the wall as shown in the cells marked 3 (Fig. 35).

When once they are free and in the cells of the tissue (see cells marked 4 in Figure 35), they put out little arms and creep about repairing any damages which the cells may have suffered.

If a sliver has been thrust into the tissue, they will gather about the sliver in such great numbers as to make a soft covering, thus protecting the tissue from further damage by the intruder. If microbes have got in, the white corpuscles will eat up the microbes, thus in most cases protecting the rest of the tissue from the action of these parasites. Sometimes, however, there are too many microbes or bacteria to be thus disposed of, when they will accumulate in the system and cause a fever or some disease.

IV. WHERE THE BLOOD LOSES ITS OXYGEN

We have mentioned how the blood becomes oxygenated in the lungs. It leaves the lungs in a bright scarlet stream; it retains this appearance until it comes to the capillaries, where it gives up its oxygen to the hungry tissues.

As soon as it loses its oxygen, it loses its bright scarlet color, becoming dark purplish red, which color it retains throughout its course through the venous system back to the heart (Fig. 36).

7. THE LYMPH AND ITS CIRCULATION

AT the end of the previous lesson we were studying the changes which take place in the blood during its passage through the capillaries. We found that blood plasma, laden with food for the cells, passes through the pores in the capillaries and oozes through the tissue, through the spaces between the cells.

We found also that the white blood corpuscles pass out

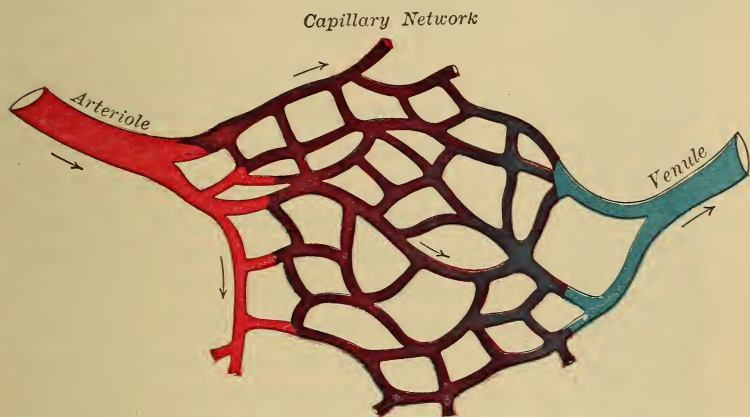


FIG. 36. — Capillary network showing change from arterial to venous blood.

through these little pores in the capillary walls. They pass out in large numbers only when there is some condition in the tissues which they can correct.

But they are continually on the lookout for danger, and an occasional white blood corpuscle may pass through the capillary at any time, so that there are always some white blood corpuscles in the tissue spaces.

The plasma and white corpuscles make up what is called tissue lymph. The tissue lymph soon becomes changed by the addition of substances thrown out through

the cells of the tissue, so that tissue lymph does not retain the same composition that the blood plasma had. As the plasma keeps coming into the tissues from the capillaries, it forces the plasma on and keeps it moving. After oozing through the tissue into which it first passed, it soon finds its way into little vessels which are like veins, except that they contain only lymph (Fig. 37).

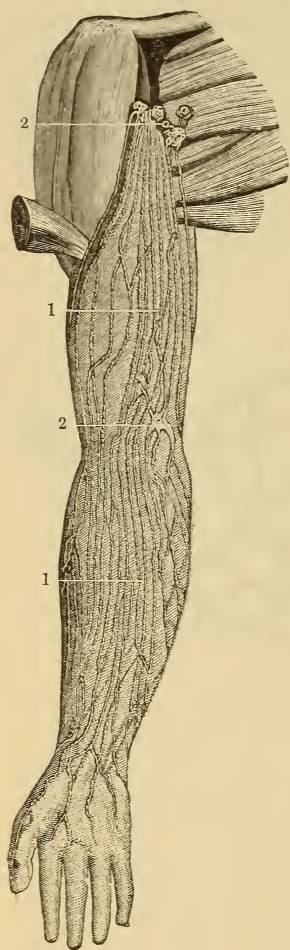


FIG. 37.—Lymphatic vessels of the surface of the arm. 1, ducts; 2, glands.

Once the lymph enters a vessel called a lymphatic, it may be called circulatory lymph; it does not again enter the tissue, but continues to move through lymphatics toward the heart in a way quite similar to that in which the venous blood moves toward the heart from the tissues. Small lymphatics come together and make larger ones, until finally a very large lymphatic vessel passing up through the abdomen and thorax receives the lymph from the other lymphatics, and finally pours it into the venous system.

In Figure 37, notice the little lymphatic glands which lie in the course of the lymphatics at 2. These glands are made up of a fine network of fibers, in the meshes of which there are innumerable little cells. As the lymph filters through

one of these glands, some of the white corpuscles which have become old and sluggish in their movements, get entangled in the network and die.

But the lymph which leaves the gland has more white corpuscles than that which enters the gland, because young corpuscles are being constantly formed in the gland, so that a lymph gland is at the same time the grave of old white corpuscles and the birthplace of young white corpuscles.

Looking again at Figure 37, you will notice that the larger lymphatics seem to have little joints, or nodes. The nodes show where the valves are located. What is the use of the valves? The pressure of new blood plasma filtering into the tissue is sufficient to keep the tissue plasma moving, but it is not always sufficient to make the lymph pass up through the lymphatics to the heart. These valves are open toward the heart, allowing the lymph to flow easily in that direction, but they close as soon as the lymph is pressed back, and do not allow it to flow away from the heart.

Now in the movements of the body, especially of the arms and legs, the lymphatics are pressed upon by the contracting muscles. This pressure forces the lymph out of the lymphatics toward the heart because it cannot go in the opposite direction, thus leaving the lymphatics empty and ready to fill very easily from behind as soon as the pressure is relieved.

From this it must be clear that muscular movements of the legs, arms, and body assist the lymph circulation (it may be added here that it assists also the circulation in the veins), and in that way assists the nutrition of the tissues. In fact, the secret of the influence of muscular exercise upon the general health lies more in its action

upon the lymphatic and venous circulations than in anything else.

An important part of the lymphatic system is that

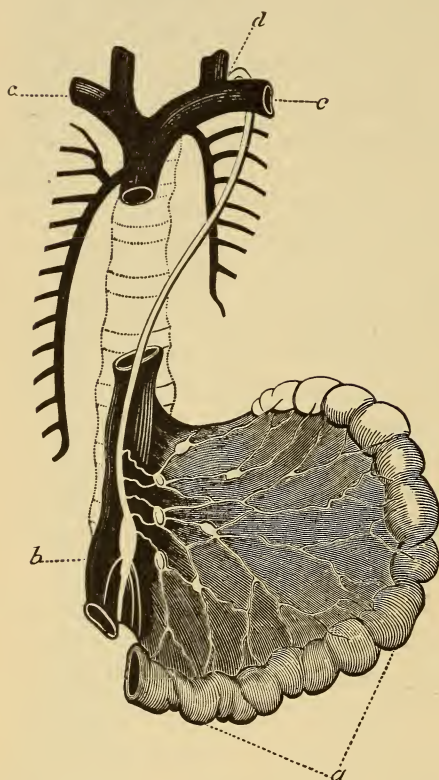


FIG. 38. — Lacteals, thoracic duct, etc. *a*, intestine; *b*, vena cava inferior; *c, c*, right and left subclavian veins; *d*, point of opening of thoracic duct into left subclavian. [Dalton.]

which collects the tissue fluid from the intestine, carrying it to the thoracic duct (Fig. 38). This portion of the lymphatic system differs from the rest in carrying absorbed foods from the intestines to the circulatory system.

The veins of the intestine carry part of the food, but the lymphatics carry all of the absorbed fat. This fat is in the form of an emulsion something like cream, and makes the lymphatics of the intestine look white, as though they were filled with milk. For this reason these particular lymphatics have been called *lacteals* (from the Latin *lac*, milk).

This white lymph is sufficiently different from the rest of the lymph of the body to have a separate name; it is called *chyle*.

8. THE CONTROL OF THE CIRCULATION

CONTROL OF THE HEART

PUT your finger upon your pulse and count the number of times it beats in a minute. Count it again and see if you can make it beat faster this time than before. You will probably find, if you have been sitting still during your counting, that it beats just about the same from minute to minute, and that you cannot of your own will make it beat faster or slower. Now if you will lie down upon a bench or couch, and breathe very deeply and very slowly for five or ten minutes, and let some one else count your pulse, you will find that it is slower than it was at your first observation.

If you take some brisk and vigorous exercise, like running up and down a flight of stairs two or three times, or running around the schoolhouse two or three times, you will find that the heart is beating very much more rapidly and strongly than at your first observation.

This experiment teaches us two things. First, that we cannot directly control the heart by the will, and, second, that there is something in the body that does control the heart. If we wish to make the heart beat faster, we can do so by making the other muscles of the body exercise, or if we wish the heart to go more slowly, we can accomplish it by decreasing the work which it has to do for the system, which was done in the experiment above when you lay down in absolute rest and in a position which reduced the work of the heart.

The heart, like the stomach, is controlled by the nervous system. There are two sets of nerves which go to the heart from the central nervous system. One of these sets

of nerves comes from the sympathetic nervous system, and the other comes direct from the brain through the vagus nerve, which passes down the side of the neck, through the thorax into the abdomen. As the vagi nerves pass the heart, they give off branches to it. The nerves which come from the sympathetic nervous system pass to the heart from the upper ganglia of that system, as shown in the diagram of the sympathetic system (Fig. 19, p. 51).

The nerves which influence the heart are shown in that figure to come from the first dorsal ganglion of the sympathetic system of both the right and left side, and also from the right and left vagus. From these various sources, the nerve fibers form a network near the base of the heart, called the cardiac plexus, or heart network.

The nerve fibers from the sympathetic system cause the heart to go faster, while the nerve fibers from the brain make the heart go more slowly. These two sets of fibers are similar to the lines and whip which the driver uses in driving his horse, — the whip making the horse go faster, and the lines holding him back. If the whip is lost, the horse may go very slowly, and the driver has no way of making him go faster. Similarly, if the sympathetic nerves leading to the heart are cut, the heart will go very slowly, and any urgent need of the system for more blood will not be responded to by the heart, because the only impulse which it can receive from the central nervous system will only make it go more slowly instead of more rapidly.

On the other hand, if the nerves which the heart receives from the vagus should be cut, the heart would begin to beat very rapidly, and the system would have no means through which to control it; and like a horse whose lines

are cut, it will go faster and faster until a disaster occurs. But when these nerves are all in order, the heart will beat slowly when the tissues of the body need little blood, and will beat rapidly when the tissues of the body need more food or more oxygen.

9. THE CONTROL OF THE CIRCULATION (*continued*)

CONTROL OF TISSUE SUPPLY

IN the preceding lesson it was explained how the heart is made to beat more rapidly and strongly when more blood is needed in the tissues, but no mention was made of the very important fact that not all of the tissues need an extra supply of blood at the same time. When one is taking vigorous muscular exercise, he is not likely to be doing much thinking, nor is he likely to be digesting a meal, so it is the muscular system alone that needs an extra supply of food and of oxygen. When the stomach is digesting a meal, it needs an extra supply of blood. It can do its work to better advantage if it can for a time, say for an hour at least, monopolize in a measure the blood flow, not having to divide with muscles or brain. In order to accomplish this, the system has a very remarkable apparatus, which consists of muscles and nerves. The muscles are those located in the walls of the arteries, especially in the smaller branches of the arteries, and the nerves are fine fibers from the sympathetic nervous system, which pass to these muscles in the walls of the arteries, and either cause them to constrict the arteries, allowing less blood to pass, or causing them to dilate widely.

Let us call the nerves which cause them to contract,

vessel constrictors, and those which cause the arteries to dilate, *vessel dilators*.

When the stomach and intestines receive food which they have to digest, the dilators of the arteries supplying these organs cause the muscles of the arteries to relax, and the supply of blood will be increased in those organs only, while the amount of blood which passes to other organs in the system will be somewhat diminished.

As another example, when one begins to perform vigorous exercise, or do hard work, the dilators of the muscular arteries will cause these arteries to dilate, thus increasing the flow of blood to the muscles.

The muscles make up so much of the tissues of the body that a dilation of the muscular arteries would cause a considerable fall in the pressure of the blood, if the central pump, namely, the heart, did not increase the rate and force of its pumping. Thus it occurs that muscular exercise leads always to an increase in the rate and force of the beating of the heart.

The heart is less modified in its beating by the work which the glandular organs or the brain may have to do, but that is because the glandular organs and brain make up so small a portion of the whole body.

The influence of these constrictors and dilators upon the arteries may be very readily observed by noticing the skin. When one goes from a warm room into cold atmosphere, the skin becomes white, and one feels chilly. That is because the little arteries of the skin have all been contracted by the constrictors, thus not allowing the blood to flow into the skin, but keeping it in the deeper organs and tissues. This is nature's method of keeping the blood warm. One's natural impulse, under such conditions, is to hurry, to move briskly. This brisk movement can

be carried on only through an oxidation of food materials within the muscle cells. But this oxidation causes heat to be given off to the blood. In a few minutes, if the system is in a perfectly healthy condition, the dilators to the arterioles of the skin will act, and the now heated blood will go into the skin and make it red and warm. If, for any reason, the blood remains in the skin at first without being withdrawn to the muscles and internal organs, it will be rapidly cooled down before the muscles have had a chance to heat it up through oxidation, as above described, and the temperature of the body will be lowered.

The nerves which assist in the control of the arteries come from the sympathetic nervous system and are much influenced by the emotions. You have all noticed how the face flushes when one is embarrassed ; this is due to the action of the dilator nerves. Various emotions may cause the flushing or blushing, for example, anger and shame. Certain emotions, such as fear or extreme rage, may cause the constrictors to act, making the face white.

10. THE HYGIENE OF THE CIRCULATORY FLUIDS AND ORGANS

I. EXERCISE

WHEN the muscle tissue is at perfect rest the blood stream is comparatively slower, and the pressure of the blood in the capillaries is not sufficient to cause a large amount of plasma to filter through the capillary walls. There is, therefore, a smaller amount of tissue plasma or tissue lymph circulating between the cells. As a further result, the stream of lymph which leaves the

muscle tissue by way of the lymphatics is also much decreased during inactivity. And the lymph which makes its way into the lymphatics, having little pressure from the tissue and little or no pressure upon the lymphatic vessels from muscular contraction, moves only very sluggishly toward the heart. This sluggish flow of lymph during rest permits waste matter to collect in the tissue plasma.

One or two periods of vigorous muscular exercise each day will, by increasing the flow of blood and lymph through the muscles, cause all this waste material to be carried out of the muscles to the organs of excretion, where it will be thrown out of the body.

We see from this how important it is for one to take exercise. The increased strength and rate of the heart-beat during exercise will cause an increased flow of blood in other tissues of the body as well as the muscle tissues, thus insuring the thorough sweeping away of waste material as well as a thorough distribution of the nourishment and oxygen contained in the blood.

Most people who live in cities and towns do not exercise enough, and some people exercise too much. Some people wish to exercise, but there may be reasons why they cannot do so.

II. MASSAGE

Such people may substitute massage for exercise. The movement of the muscles of an arm or leg, or pressure upon the tissues of arm or leg or body, will cause an increased flow in the lymphatics and veins, even when some one else takes hold of the arm or leg and moves it for one.

This passive exercise is called massage, and is an important means of insuring nutrition and an elimination of waste materials in inactive tissues.

The most efficient kind of massage is kneading of the tissues and rubbing. If a boy has so-called "growing pains," which is really rheumatism from some exposure to wet or cold, his pains will be much relieved if the aching part is thoroughly rubbed or pressed, always beginning at the most distant part and working toward the heart.

This will gradually work out the lymph and venous blood from the tissues and cause fresh blood to circulate through the tissues, carrying away from them those waste materials which are irritating the nerves and causing the pain.

III. TIME FOR REST AND TIME FOR WORK

We found that vigorous exercise takes most of the blood to the muscles. The digestion of a heavy meal takes most of the blood to the digestive system, while heavy brain work takes a large portion of the blood to the brain.

Every one knows that it is impossible to do hard thinking and hard muscular work at the same time. The reason is, that the muscles take the blood and leave the brain without sufficient supply of nutriment or oxygen to carry on its work vigorously.

Whenever the muscular system is working hard at the same time that some other system of organs is attempting to do its work, the muscular system gets the blood, and the other system is robbed of the supply necessary to do its work properly.

If one attempts to do heavy work after a heavy meal, he may do the work, but the meal either will lie undigested or will digest very slowly. Oft repeated attempts of this kind will so derange the digestive system that it refuses to do its work properly, and we say the person has indigestion or dyspepsia. A very light meal of very easily digested food may be followed almost at once by vigorous exercise, without causing serious injury to the digestive organs. A heavy meal should be followed by at least an hour of rest, or at most very little exercise in the open air.

IV. THE CONDITION OF THE BLOOD

You see how important it is for the health and strength of the body that the blood should always contain sufficient nutriment for the tissues, sufficient oxygen for tissue oxidation, and should be kept free from accumulated waste materials.

One of the most frequent diseases of the blood is called anæmia, and consists of a decrease in the number or in the quality of the red blood corpuscles. The red blood corpuscles carry oxygen to the tissues; if these are decreased in number the tissues will suffer for want of sufficient oxygen.

The best way to avoid anæmia, or the best way to recover from it, is to eat plenty of nourishing food. It is understood, of course, that the digestive system is in good condition, otherwise the plenty of nourishing food could not be properly utilized by the system. Foods which are rich in iron should form an important part of the dietary; such foods are eggs, the cereal foods, beans, peas, spinach, and so forth.

11. THE INFLUENCE OF NARCOTICS UPON THE CIRCULATORY FLUIDS AND ORGANS

I. THE EFFECT OF ALCOHOL UPON THE BLOOD

ALCOHOL is absorbed from the alimentary canal unchanged by the processes of digestion. It passes into the blood vessels in the walls of the stomach and intestines, and is distributed by the blood throughout the system. Dr. Woodhead, Professor of Pathology, Cambridge University, England, believes from the work of various medical men, whose authority he quotes, that the white blood corpuscles are injured by the presence of alcohol in the blood, and made less active in their work of defending the system against the germs of disease, therefore leaving the system more exposed to various germ diseases.

II. THE EFFECT OF ALCOHOL UPON THE HEART

The occasional and moderate use of alcoholic drinks influences the action of the heart. "Wherever a distinct effect is made upon the system by alcohol, this is always indicated by the pulse. The action of the heart is quickened for a time, afterward becoming enfeebled until another dose of poison is taken to revive it. In time, this becomes the ordinary condition, and is accompanied by general changes in the action of the whole circulatory system. These changes in the action of the heart and arterioles lead to changes in the structure of the heart and blood vessels."¹

Professor Destree ("Influence of Alcohol on the Muscu-

¹ Geo. H. McMichael, M.D., Buffalo, N.Y., in the *Dietetic and Hygienic Gazette*, May, 1897, p. 278.

lar System") believes that the increased action of the heart under the influence of alcohol is only apparently a stimulation, resulting partly from the paralysis of the muscular walls of the arterioles, thus allowing them to dilate and reducing blood pressure, which the heart tries to correct by beating more rapidly, and resulting partly from irritation of the mucous membrane of the stomach by the alcohol. This irritation affects the heart through the sympathetic nervous system.

But the heart is not only modified in its action by the influence of alcohol, it is also modified in its structure. "The heart, from continued overaction, becomes dilated, and its valves are relaxed. The membranes which envelop the organ are thickened, rendered cartilaginous, and occasionally calcareous. The valves, which consist of folds of membrane, lose their suppleness and become diseased and weakened. The muscular fiber of the heart is replaced by fatty cells, so that the power of contraction is greatly reduced. These derangements are liable to cause death from sudden failure of the heart itself, from rupture of the blood vessels, from oozing of the blood in the brain, producing apoplexy. . . . There is always danger of the heart failing to do its work, for alcohol has made it inefficient." ¹

III. THE EFFECT OF ALCOHOL UPON THE BLOOD VESSELS

From what has been said in a previous lesson about the muscular walls of the arteries and arterioles, it is plain that it is very important to the system that the arteries retain their power to respond quickly to the needs of the system, now expanding, and now contracting. But under

¹ G. H. McMichael, M.D., *Journal of Inebriety*, July, 1897, p. 258.

the influence of alcohol, even when used in moderate quantities for a long period of years, the walls of the blood vessels become changed, especially the arteries and arterioles. The connective tissue of the arteriole wall becomes much increased, thus making the wall thick and inelastic. Frequently lime salts are deposited in this connective tissue, making the wall of the artery brittle and liable to burst when there is any unusual strain put upon it. Now this weakening of the walls of the blood vessels is especially frequent in the arteries of the brain. Upon the occurrence of anything which causes a sudden increase in the heart's action, thus forcibly distending the arteries, rupture is likely to occur, thus causing hemorrhage of the brain, taking the form either of apoplexy or paralysis.

IV. THE EFFECT OF TOBACCO ON THE HEART

Dr. J. W. Seaver, a professor in Yale University, in an article on "The Effects of Nicotine," calls attention to the fact that the heart action is increased when tobacco is being used, that the increase is due, not to stimulation of the heart, but to partial paralysis of the vagi nerves. From previous lessons you know that the vagi nerves hold the heart in check, causing it to reserve its power as much as possible for legitimate emergencies; now if the vagi nerves are paralyzed, the heart beats rapidly, thus unnecessarily wearing itself out. With this information we can easily understand how in the beginning of the habit of smoking, the influence of the nicotine causes so much disturbance to the circulation, for the vagus is the great controlling nerve of the heart, and that organ is the first to respond to the poison.

REVIEW OF THE CIRCULATION

1. The body needs a system of tubes through which the liquids of the body can circulate, just as much as a city needs a system of tubes and pipes through which the water can circulate and the drainage and sewage be carried away.

2. The *blood* and *lymph* are the liquids which circulate through the body. The blood is composed of *plasma* in which float *red* and *white cells* or *corpuscles*. The *lymph* is composed of *plasma* in which float white cells or *corpuscles*.

3. The *blood* and *lymph* carry *food* to the working cells, tissues, and organs of the body.

4. The *blood* and *lymph* carry *waste matter* from the working cells, tissues, and organs of the body to the place where this matter is to be thrown out of the body.

5. If a blood vessel is cut, the blood *clots* or *coagulates* and *stops* the wound, unless a large artery or vein is cut.

6. The blood is carried to different parts of the body in *arteries* and brought back in *veins*. It oozes through fine *capillaries* as it passes through the different tissues.

7. The *heart pumps* the blood through the arteries, capillaries, and veins. Each contraction of the heart—each *heart beat*—sends blood into the arteries. *Valves* at the entrance of the aorta keep the blood from flowing back into the heart while the heart is being filled with the blood from the veins.

8. When the heart forces blood into the arteries, it starts a little wave along all the arteries. One can feel this wave wherever the arteries come near to the skin. This wave is called the *Pulse*. Where may pulses be felt?

9. The *blood carries oxygen* from the lungs to the tissues, and *carbon dioxide* from the tissues to the lungs.

10. The *heart is controlled by two sets of nerves*: one set (*sympathetic*) makes it beat faster and stronger, while the other (*vagus*) makes it beat more slowly. If the *vagus* be stimulated, the heart will beat more slowly; if the *sympathetic* nerve be stimulated, the heart will beat more rapidly. If the *vagus* be cut or narcotized, the heart will beat faster; if the *sympathetic* be narcotized, the heart will beat more slowly.

11. The *arteries are controlled by two sets of nerves*. The *Constrictors* make the arteries smaller and allow less blood to flow into the tissues. The *Dilators* make the arteries larger and allow more blood to flow into the tissues.

12. When one exercises his muscles, the vessel dilators allow more blood to flow to the muscles. The heart also works harder and sends a faster current of blood over the body. One should not exercise severely just before or just after a meal. *Every one needs exercise in the open air.*

13. *Nourishing food and out-of-door exercise, with well-ventilated homes and schoolrooms, will keep the blood pure and the body healthy.*

14. *People who use alcohol are more subject to disease than are those who do not*; because the body, especially the blood, is less resistant to the germs of disease.

15. *Alcohol makes the heart beat faster*; because it narcotizes or dulls the influence of the vagus nerve. Explain how this can be.

16. *Alcohol makes the blood vessels of the skin dilate*, and so the skin looks red and the person feels warm; but the blood gives up its warmth to the air, and the temperature of the body falls. Alcohol also causes the walls of the blood vessels to become weak.

17. *Tobacco causes the heart to beat faster* than usual because the vagus nerve is narcotized.

CHAPTER VII. — RESPIRATION — HOW THE BLOOD IS PURIFIED

1. THE NEED FOR A RESPIRATORY SYSTEM

IN our study of the plant we found that oxygen is necessary for its life processes ; that the energy required by the little germinating plant to push aside the little particles of soil and appear above the surface of the ground, can be obtained only by oxidation of some of the plant material.

The oxygen which enters into the oxidation comes from the atmosphere ; the material oxidized is part of the plant body, and the result of the oxidation is liberated energy and waste products, comprising in the plant especially water and carbon dioxide.

In a one-celled animal such as the *amœba*, we found the same general principles to be true, and that every motion of the *amœba* required an oxidation of a portion of the substance of the little animal, the oxygen coming from the surrounding medium, the oxidation resulting in the formation of waste products, among which carbon dioxide and water take a prominent part.

Every active cell in our bodies requires oxygen in order to enable it to do its appointed work. If it is a muscle cell, the energy of heat and motion which it must generate for the body can only come from the oxidation of muscle cell protoplasm or muscle cell sap. If the cell is a gland cell, it cannot do its work of forming new substances without the presence of oxygen, which takes part in the changes

that the cell makes in the substances which it absorbs from the blood. If it is a brain cell, oxygen is just as necessary, though perhaps used in somewhat smaller quantities than would be the case in a muscle cell.

Respiration is the process of furnishing oxygen to the active cells of the body. The one-celled plants and animals need no apparatus to carry the oxygen to the different parts of their system, because their minute bodies are surrounded either by the atmosphere, which is one fifth oxygen, or by water, in which oxygen from the atmosphere is freely dissolved. But in all animals except the simplest ones, large portions of the body are so far removed from contact with the atmosphere or water that these animals require a special apparatus or system of organs devoted to this work of supplying the inside tissues of the body with oxygen. This function is called respiration, and the system of organs which performs this function is called the respiratory system.

Animals that live in the water breathe by means of gills; animals that live on land breathe by means of lungs. Some animals live in the water when they are young, and change and turn into land animals when they reach maturity. Such an animal is the frog: the tadpole breathes with gills, but the frog breathes with lungs. Some animals which live in the water do not remain under water long at a time. The turtle and the crocodile are water reptiles which breathe by means of lungs. The whale, the seal, and the walrus are water mammals that breathe with lungs; none of these animals can stay under water for a long period.

Every one has seen the gills of a fish, and will remember that they are composed of delicate, velvety branches which are protected behind a scalelike shield on the side

of the fish's head. The fish draws water into the mouth, and closes the mouth, but instead of swallowing the water, presses it out the sides of the pharynx so that it passes over the gills which absorb the oxygen held by the water in solution.

The lungs are elastic air sacs, which are made of very delicate tissue and lodged within the body cavity. The animal draws the air into the lungs, where it remains for a short time giving up its oxygen to the blood which is circulating within the capillary branches of the pulmonary artery. The drawing in of the air is called *Inspiration*, and the throwing of the air out of the lungs is called *Expiration*.

That part of respiration which includes the inspiration of the air, the absorption of the oxygen, and the expiration of the air laden with carbon dioxide, is called *external respiration*, while that part of the respiration which includes the distribution of the oxygen to the tissues by the blood and the absorption of the oxygen from the blood by the tissues, also the giving up of carbon dioxide to the blood by the tissues and the transportation of this carbon dioxide gas by the blood to the lungs, is called *internal respiration*.

2. THE ORGANS OF RESPIRATION

THE lungs have already been mentioned as organs of respiration, and they are the most important organs of the respiratory system. Figure 39 shows the lungs within the chest or thorax. Notice from the figure that there are two lungs, one on either side of the heart. These lungs are hollowed out to make a space for the heart.

The pulmonary artery (*D*) branches under the arch of the aorta, sending part of the blood to each lung. The

heart is not in the middle of the thorax, but just a little more on the left side than on the right, so that the left lung is a little smaller than the right lung. The two lungs and the heart rest upon the muscular partition which separates the thorax from the abdomen. This muscular partition is

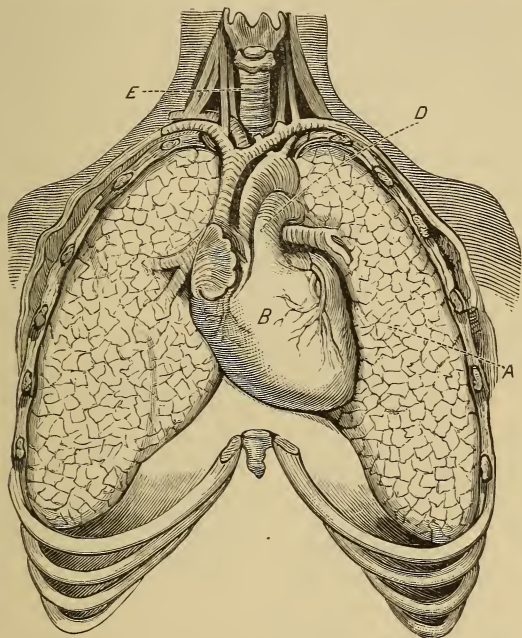


FIG. 39.—The cavity of the chest, showing the positions of the heart and the lungs. *A*, left lung; *B*, heart; *D*, pulmonary artery; *E*, trachea, or windpipe. [Tracy.]

called the *diaphragm*. Notice from the picture that the diaphragm is higher in the middle than at the edges; in other words, it is arched upward. As the diaphragm is the principal muscle for drawing air into the lungs, we must name it among the respiratory organs. The air is carried to the lungs through a large tube in the neck called the *windpipe*, or *trachea*. The upper part of the

trachea is the *larynx*, or Adam's apple which one can feel in the throat.

The air in passing into the trachea must pass through the *pharynx*, and to get into the pharynx it must pass through either the mouth or *nose*. Nature intended that the nose should be the air passage, but many people breathe through the mouth because of some temporary or permanent obstruction in the nose. The nose is made especially for breathing; it is provided with a moist mucous membrane for catching the dust; it is full of blood vessels for warming the air. To assist in catching the dust, there are, near the opening of the nose, hairs kept moist by secretions. The passage through the nose is not simply a cylindrical canal, but very irregular, with folds which increase the surface, and not only aid in warming the air and removing the dust, but also aid the sense of smell by increasing the amount of surface exposed to odors.

The larynx contains the *vocal cords*, and is the organ for producing the voice, and so is sometimes called the voice box. One can feel the little point of his larynx, and by passing the fingers along the throat below the larynx he can feel the large, stiff tube whose walls contain little rings of cartilage. The object of these rings is to keep the trachea open. If it were not for these the trachea would collapse, and the breath would be shut off.

Notice that down in the thorax between the two lungs the trachea branches into two parts, each looking quite like the trachea, only smaller (Fig. 40). These two parts are *bronchi*. Each bronchus subdivides within the lung into a series of treelike branches, until finally every portion of the lung substance is reached by minute terminal twigs of this system of branches. The divisions of

the bronchi are called *bronchial tubes*. The bronchial tubes end in clusters of *air cells*, which are similar to bunches of grapes. In the figure only a few of these clusters are shown, but the lung is made up largely of innumerable clusters lying side by side.

The air passages consist, then, of nose, pharynx, larynx, trachea, bronchi, bronchioles, and air cells. All of the air passages are *lined with mucous membrane*. The mucous membrane of trachea, bronchi, and bronchioles is provided with *ciliated cells*. These cilia are always moving with an

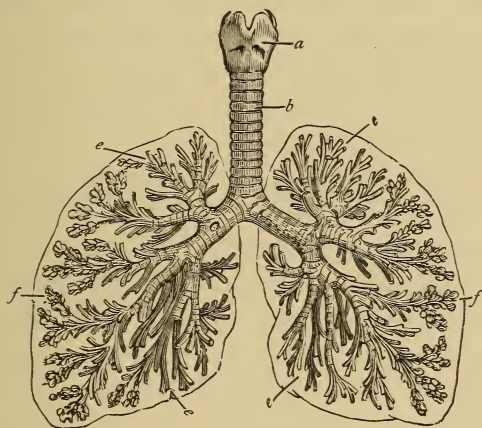


FIG. 40. — Air passages in the human lungs. *a*, larynx; *b*, trachea; *c*, *d*, bronchi; *e*, bronchial tubes; *f*, cluster of air cells.

upward, whiplike motion, which carries particles of dust and mucus up the trachea until it reaches the larynx, where it causes a tickling sensation and is coughed up.

The branches of the pulmonary artery pass into the lungs by the side of the bronchi, and subdivide wherever the bronchi subdivide, being finally distributed in small branches to each cluster of air cells. The end branches of the pulmonary artery send to each cluster one or more

arterioles, which break up into a network of capillaries similar to that shown in Figure 35, so that each air cell is surrounded by a network of capillaries.

We must not forget that the pulmonary artery carries impure blood to the lungs for purification, so that the arrows in Figure 36 will need to be reversed, the impure blood passing in from the arterioles and becoming purified as it passes through the capillary system, and then, passing out into the pulmonary veins, finally collects into four pulmonary veins which empty into the left auricle.

The blood which circulates in the lung capillaries is separated from the air by the delicate mucous membrane of the air cell, the capillary wall, and a film of plasma; yet we shall find that there is ample opportunity for the blood to be purified.

3. THE MOVEMENTS OF RESPIRATION

THE diaphragm has already been mentioned as the most important muscle of the respiratory system. Reference to Figure 39 will show the diaphragm arching upward, filling the space in the middle of the thorax and passing up to the heart. The lower lobes of the lungs fill the space between the high dome of the diaphragm and the wall of the thorax. Just below the diaphragm lie the stomach and liver, not shown in the figure.

The muscular fibers of the diaphragm radiate outward from its center and are attached around the thoracic wall. The contraction of the diaphragm is brought about by all these fibers contracting at the same time. It must be easily seen that when the diaphragm contracts its dome will be flattened. Now the diaphragm is the partition wall between the thorax and the abdomen. The flattening of the diaphragm is really a moving of all the dia-

phragm except its margins from the thorax toward the abdomen. That would tend to make more room in the thorax, and also to push the stomach and liver downward further into the abdominal cavity.

What would happen in the abdominal cavity is very easily understood. The stomach and liver push upon the intestine and all of these organs are pressed outward in every direction, and so distend the walls of the abdomen.

It may not be so easy to understand just what takes place within the thorax. We know that when we draw up the piston of a syringe the air or water will rush through the nozzle of the syringe and fill up the space that would be left, so that there is really no vacant space in the syringe, that is, no vacuum.

In a similar way, when the diaphragm pulls downward toward the abdominal cavity it would tend to leave a vacuum around the lungs and heart, but the air rushes in at the nose and through the air passages, filling the lungs and allowing them to expand and fill up all of the space made by the contraction of the diaphragm.

The diaphragm is not the only muscle of respiration; the diaphragm makes only one wall of the thorax, a partition wall between the thorax and another body cavity. The outside walls of the thorax are also movable, though in a much smaller degree than is the case with the diaphragm. The curving ribs slant downward and forward from the backbone, and are so attached to the backbone that when the front ends are raised, the front wall of the chest, as well as the side walls, will be thrown out, thus increasing the space within the thorax, which the lungs swell out and fill (Fig. 41). The muscles which do this are the muscles which pass from the backbone to the collar bone and upper ribs, also the inter-

costal muscles, which attach each rib to the next rib below it.

The filling of the lungs is called *inspiration*. The lungs are alternately filled and emptied. The emptying of the lungs is called *expiration*. When the lungs are to be

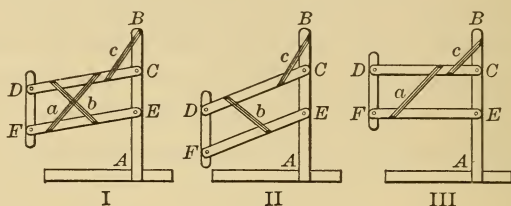


FIG. 41.—Diagram illustrating the increase in the diameter of the thorax when the ribs are raised.

emptied the diaphragm relaxes, and the muscles which have raised the ribs relax, the chest walls fall back to their position of rest; the abdominal walls, which have been distended by the pressure of the organs within come back to their position of rest, which pushes the diaphragm up into the thorax again, thus restoring to its position of rest all the muscles of respiration, and the ribs as well as the lungs.* As the walls of the thorax pass inward toward the lungs, they contract, and the air flows out of the nose.

4. THE MOVEMENTS OF RESPIRATION (*continued*)

I. FORCED BREATHING

THE breathing described in the preceding lesson is what is called quiet breathing. This is the way one breathes when he is sitting quietly or when asleep. The air which flows out and in the lungs in quiet breathing is called *tidal air*, and amounts to about 30 cubic inches, or a little over a pint, for the average-sized adult man.

If one will observe his respiration when he is breathing quietly he will get a good idea of how much air flows out of and into the lungs, and how much movement of the chest and abdomen there is in quiet breathing. At the end of a quiet inspiration one is able to continue to draw air into the lungs. He can go on expanding his chest and abdomen until he reaches the limit of his capacity, drawing in about 100 cubic inches more of air. This extra air which one is able to draw into the lungs in a forced inspiration is called *complemental air*. In forced inspiration, all of the muscles of quiet inspiration are in use, contracting much more strongly than in quiet breathing, and besides these, muscles of the back and shoulders assist in raising the ribs and sternum.

If, at the end of a forced inspiration, one begins to let the air flow out of the lungs, the 100 cubic inches of *complemental air* will flow out first, followed by the 30 cubic inches of tidal air. After these 130 cubic inches have escaped from the air passages and the muscles of respiration are in position of perfect rest, one may still force air out of the lungs. This is called *forced expiration*, and is accomplished mostly by the contraction of the walls of the abdomen. This forces the intestines, stomach, and liver backward and upward against the diaphragm, thus forcing the diaphragm farther up into the chest cavity and forcing air out of the lungs. This air of the forced expiration is called *reserve air*, and amounts to about 100 cubic inches, but there is still remaining in the lungs air which one cannot force out voluntarily. This air that always remains in the lungs is called *residual air*, and amounts to about 100 cubic inches. Though this residual air cannot be voluntarily forced out, it is sometimes forced out accidentally. If one falls upon his shoulders, or if

through any accident the chest is suddenly compressed at the end of an expiration, a portion of the residual air may be forced out. In such a case one feels distressed and has difficulty in regaining the breath.

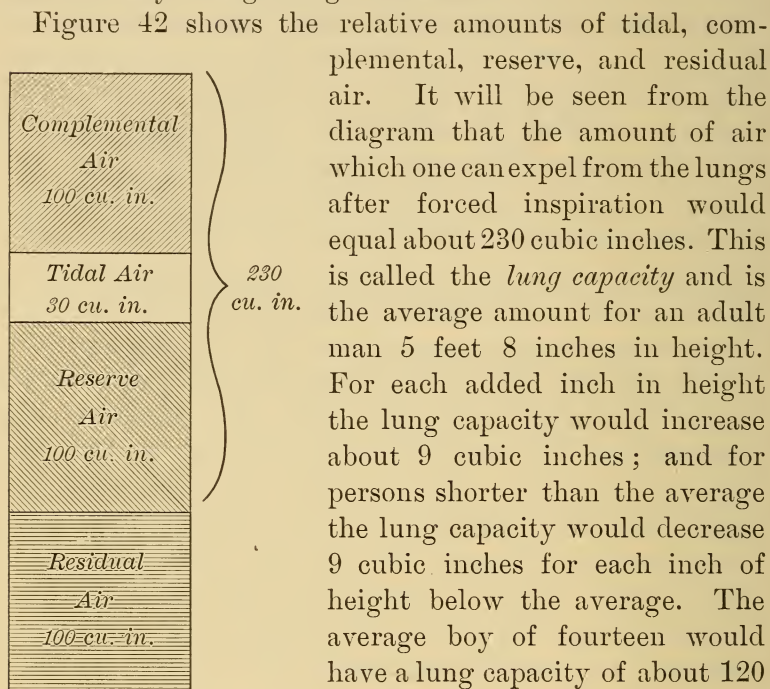


FIG. 42. — Diagram showing the relative amounts of tidal, complementary, reserve, and residual air. Note that the brace shows the average lung capacity for the adult man.

II. CHEST AND ABDOMINAL BREATHING

It is frequently said that women breathe differently from men, the chest movement being more pronounced in

a woman and the abdominal movement in a man. The best authorities agree now that there should be no difference in the breathing of men and women; if there is a difference it is because of the unhygienic clothing so frequently worn by women.

5. BREATHING AND THE VOICE

I. HOW THE BREATHING IS CONTROLLED

THE movements of the diaphragm are controlled by the *phrenic nerves*, which can be traced upward from the thorax and the deep muscles of the neck into the spinal cord and up to the medulla oblongata, situated at the base of the brain.

The intercostal muscles are controlled by the intercostal nerves, each one of which passes directly into the spinal cord and upward to the medulla. These are the nerves which control the muscles of inspiration. The lower intercostal muscles which control the muscles of the abdominal walls are expiration nerves.

The sensory nerves of the nose and those branches of the vagus nerve which supply the larynx and the mucous membrane of the lungs, are the sensory nerves of respiration.

II. MODIFICATIONS OF BREATHING

If mucus or any foreign body gets into the larynx it irritates the sensory nerves, a message is sent to the breathing center in the medulla, from which a message is sent to the abdominal muscles, which contract quickly, causing a *coughing*, which dislodges and throws out the offending substance.

When the membrane of the nose is irritated in any way, a similar explosion of the air through the nose will generally remove the irritating matter. This act is called *sneezing*.

Yawning is a deep inspiration in which the lungs are well filled and inflated, furnishing an extra supply of oxygen for the system.

Hiccoughing consists of a sudden contraction of the diaphragm, which causes a spasmodic inspiration; this is blocked by the sudden closure of the larynx, causing a "hiccough."

Sighing is similar to yawning but is caused by such emotions as grief or sorrow.

Crying and *Laughing*. These are combined modifications of breathing and the voice. They are caused by the emotions, and consist of a deep inspiration, usually followed by a series of spasmodic expirations which are vocalized or in which the voice is acting.

Sobbing is a convulsive inspiration, also emotional, and usually follows prolonged crying.

III. THE VOICE

In describing the organs of respiration the larynx or voice box was mentioned. In the upper part of the larynx two membranes pass out from the sides toward the middle. The edges of these membranes are rounded cords which are so attached to the walls of the larynx that they may be brought close together and stretched tightly through the contraction of the muscles in the walls of the larynx. These cords are the *vocal cords*. When the vocal cords are tightened and brought near together, the air passing over them sets them to vibrating. This

vibration causes a sound which we call *the voice*. Most of the higher animals have a voice. Animals that have a voice use it in the expression of their emotions and desires first of all. A child first uses its voice for this purpose. When it begins to talk it expresses other ideas.

Man has cultivated his voice along with his mind, so that he is able to express, not only the emotions and desires, but a continuous train of thought in a succession of sounds which we call *speech*. These sounds are grouped into syllables and words; each syllable contains at least one vocal or vowel sound which is made by the larynx and which is more or less modified by the organs of articulation. These modifications of the vocal sounds are termed consonants, and they are produced by the various positions of the lips, tongue, teeth, and palate during the formation of the sound by the larynx.

In the word or syllable *bat*, the larynx makes the vocal or vowel sound *a*, and this vowel sound is introduced by the lip consonant (labial) *b*, and followed by the tongue-palate consonant (palato-lingual) *t*.

The vowels of the English language are *a*, *e*, *i*, *o*, and *u*, which may be modified in quality by the vocal organs to make about seventeen different sounds.

The consonants, about twenty-one in number, are subdivided into the labial or lip consonants, *p*, *b*, *w*; the labio-dental or lip-teeth sounds, *f*, *v*; the linguo-dental or tongue-teeth sounds, *th*; the nasals, *m*, *n*, *ng*; and the palato-linguals or palate-tongue sounds.

People of culture and refinement usually possess voices which are under perfect control under all circumstances, never pitched too high or too low; when they speak their voices are well modulated and their words are distinctly enunciated.

6. HOW THE AIR IS CHANGED IN THE LUNGS

I. THE COMPOSITION OF THE AIR

AIR is a mixture of gases. The mixture is composed chiefly of *nitrogen* (about four fifths), oxygen (about one fifth), with a very small amount of *carbon dioxide*. There are minute portions of other gases, because other gases than those mentioned above are escaping into the atmosphere as the result of various natural phenomena; some sulphurous and other gases may escape from volcanoes, and what is called marsh gas escapes from decaying vegetable matter in swamps. There escape into the atmosphere which is over great cities and manufacturing centers, large quantities of various gases, among them illuminating gas, and sulphurous gases from the combustion of low grades of coal, also quantities of carbon monoxide gas and of ammonia gas. But when one remembers that the atmosphere is at least forty miles deep over the whole earth, and that it is being constantly stirred up by the winds, and that the noxious gases are gradually dissolved in the surface waters of the earth, and that the carbon dioxide gas is being consumed by the plants for food, it must be clearly seen that the proportion of these noxious gases in the general atmosphere is too slight to take into consideration.

Besides all of the gases which go to make up the atmosphere, there is the water of the atmosphere, which is a most important constituent, but which is not usually included among its gases. Most of the water of the atmosphere is in the form of an invisible vapor which the atmosphere takes up from the surface water of the earth. Warm air takes up more than cold air. In your physical geography you will learn that when warm air which is

saturated with invisible moisture is cooled, the moisture collects in minute drops which gather in a visible cloud. When one breathes into the cold winter air he can see the cloud of vapor passing from his nostrils. This vapor is invisible while it is in the air passages, and becomes visible only when it passes out into the cold air, where the moisture is collected into drops. The clouds that float through the air are masses of visible vapor. The moisture of the atmosphere is very important to consider in the hygiene of the lungs.

The nitrogen of the atmosphere is colorless, tasteless, odorless, and is one of the most inactive gases known to chemists ; the oxygen of the air is also colorless, odorless, and tasteless, but is the most active gas known to chemists, and is the most universal in its combination with other elements, so that it enters into the composition of the water which covers so large a part of the earth's surface and, practically, every rock in the earth's crust, and forms a large part of every plant and animal living upon the earth. Our studies in the physiology of plant and animal nutrition teach us that it is through the combination of oxygen with the tissue elements that all plant and animal energy is liberated or generated.

II. THE CHANGES WHICH THE ATMOSPHERE UNDERGOES IN THE LUNGS

We take air into the lungs for its oxygen. When air is drawn into the lungs but once and exhaled in a normal way, it loses about one fourth of its oxygen. If the air lost the same amount when rebreathed, all of the oxygen would be consumed if the same air were breathed four times. But when the air is rebreathed, only one fourth of

the *remaining oxygen* is absorbed ; thus less and less is taken at each rebreathing of the air. And if one were shut into a very small space, he would take out one fourth of the oxygen in breathing the air the first time, and about one fourth of the remainder the second time, and so on, always taking one fourth of the remainder at each successive rebreathing of the air, until finally nearly all the oxygen would be exhausted. The death of the individual would soon follow, of course.

Besides the change in the oxygen, carbon dioxide is added to the air. A little smaller quantity of the carbon dioxide is added than enough to make up for the oxygen which is taken away, so that the air exhaled is a little less in quantity than the air inhaled when measured under the same conditions.

If the inspired air is dry it will take up moisture from the air passages ; and so carry away a certain amount of water from the system. It will always carry away water from the system unless it has the same temperature as the air passages, and is saturated with water at that temperature.

Besides the subtraction of oxygen and the addition of carbon dioxide and water, there is a change of temperature, the exhaled air being warmed to nearly the temperature of the blood, and there is also an addition of a small amount of organic matter carried away from the air passages.

7. HOW THE BLOOD IS CHANGED IN THE LUNGS

I. HOW THE BLOOD IS OXYGENATED

It has been stated in a previous lesson that the work of the red blood corpuscles was to carry oxygen from the lungs to the tissues. The first question which arises is,

how does the oxygen get from the air cells of the lungs to the red blood corpuscles? When a gas is in contact with the surface of a liquid, directly or through a moist membrane, the gas will pass into the liquid direct or through the membrane, rapidly at first, and more slowly later, until there is no more absorption of the gas, when we say the liquid is saturated. If the liquid is flowing past the membrane, the process of absorption of the gas will go on at the same rate, because the liquid is continually renewed.

Between the air in the air cell and the red blood corpuscles in the capillaries of the lungs there intervene (1) the thin membranous wall of the air cell, (2) a thin submucous coat whose spaces are filled with lymph, (3) the wall of the capillary, (4) the plasma within the capillary. Then comes the red blood corpuscle (Fig. 43, *a*).

Every space between fibers and cells is filled with plasma or lymph and the cells themselves are composed largely of water, so that the oxygen readily passes through the membranes and fluids just mentioned, and finally reaches the red

blood corpuscle which is floating along in the capillary.

Now red blood corpuscles have a strong affinity or appetite for oxygen, and immediately take up from the

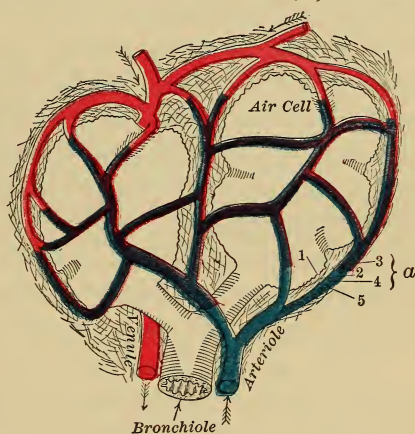


FIG. 43. — Diagram of two air cells, showing the capillary network which covers them, and at *a* the structures which intervene between the air and the blood are indicated: 1, mucous membrane of the air cell; 2, submucous meshwork; 3, wall of capillary; 4, plasma in capillary; 5, red blood corpuscle.

plasma the oxygen which comes in, and pass on, leaving the plasma as poor in oxygen as it was to start with ; so that more oxygen readily passes into the capillary, and finds the plasma and corpuscles ready to take it up at once and carry it off to the tissues.

II. HOW THE BLOOD IS FREED OF CARBON DIOXIDE

The blood leaves the tissue with a heavy load of carbon dioxide, which is carried away from the tissues to be thrown out of the system. This carbon dioxide is carried partly by the red blood corpuscles and partly by the plasma of the blood.

If a pint of venous blood were to be put under an air pump, and a vacuum made over it, carbon dioxide would pass off from it, and if this were measured at standard atmospheric pressure and at zero degrees, there would be forty-five or forty-six per cent as great volume of gas as there was volume of blood.

If arterial blood were tried in the same way, a volume of carbon dioxide equal to about forty per cent of the volume of the blood could be drawn off.

From this it seems that the blood always has carbon dioxide in it, carrying a big load from the tissues to the lungs and a somewhat smaller load from the lungs back to the tissues, so that it gives up only about one ninth of this load in the lungs.

Whether this carbon dioxide gas is given up from the corpuscles or from the plasma is not known, and part is probably given from each. The reason the carbon dioxide gas leaves the blood and passes into the air cells of the lungs is because there is very little carbon dioxide gas in the air cells of the lungs and a great deal in the blood, and so it

naturally diffuses toward the lungs ; and during the time the venous blood is passing through the capillaries, one ninth of the carbon dioxide will have time to diffuse into the air cells, while the red blood corpuscles are taking their load of oxygen for the tissues.

8. TISSUE RESPIRATION AND BODY HEAT

THE real object of the whole process of respiration is to furnish oxygen to the tissues and to carry away from the tissues the carbon dioxide. Each cell is neither able to build up its own protoplasm nor to do its special work without oxygen. When the supply of oxygen stops, all work stops. The active tissues always want oxygen, though they may want more oxygen at one time than at another. The harder they work, the more oxygen they want; when one is doing hard, muscular work, or exercising vigorously, the muscles all over the body call for more oxygen. They make this call through the help of the sympathetic nervous system. This causes the respiratory muscles to act more vigorously, so that the breathing is deeper and more rapid, more oxygen is brought into the lungs, more is taken up by the blood.

At the same time that the lungs are working harder, the heart is working harder, thus making a more rapid stream of blood through the lungs, and this takes up the oxygen more rapidly, so that the amount of oxygen carried in any particular quantity of blood during exercise need not be greater than that carried by the same quantity of blood during rest.

The affinity or appetite of the tissues for oxygen is always stronger than that of the red corpuscles, so that when a corpuscle comes to the capillaries and moves

slowly along them between active tissue cells on either side which are calling for its load of oxygen, it has to part with this load and return by way of the veins to the lungs for another load of oxygen. Active muscle, gland, and nerve cells are constantly giving off carbon dioxide into the tissue plasma which surrounds the cells. The blood in the capillaries has less carbon dioxide than that outside of the capillaries in the tissue, so that carbon dioxide diffuses from the tissue plasma into the blood plasma, and thus loads the blood with carbon dioxide, which is carried by way of the veins to the lungs, and there given up in the way described above.

I. BODY HEAT

Aristotle believed that the heat of the body was made within the heart by a combination of the "vital spirits" with the blood. For over two thousand years it was believed that the heat of the body was generated in the blood.

Lavoisier, who discovered oxygen and the principles of oxidation, believed that heat was generated in the blood of the lungs where the oxygen first entered it. After his time, and until recently, the heat was believed to be generated within the capillaries of the active tissues; but since the importance of the cell has become understood, it is generally believed that nearly all, if not quite all, of the oxidation of the substances of the body takes place within the living cells, so that the active tissue cells, whose substance is being oxidized, are the heat generators.

The muscle tissue comprises four fifths of the active tissue of the body. Muscle tissue is always generating heat energy, and some of the time it is generating both heat and motion. As the blood circulates through the

muscles it becomes heated, and then flowing to other parts of the body it distributes this heat so that all parts of the body are kept warm, the deeper tissues of the body being kept warmer than those near the surface. The temperature of the body is regulated partly by the regulation of the rate of *heat generation* and partly by the regulation of *heat radiation* from the body. The body is giving up heat to the cooler atmosphere all the while. As much as three fourths of all the energy of our food is required to keep the body warm; the rest is devoted to body building and to the movements and other activities. If one goes out into the cold winter air, the blood at first withdraws to the deeper tissues, then is sent to the muscles, where an extra supply of heat is being generated, and after being warmed in the muscles, passes to the skin to warm the surface of the body. If the body becomes too warm, the blood will go to the skin, and the sweat glands of the skin will pour out perspiration upon the surface, and so the body will be quickly cooled.

Thus we see that these two things working together, heat generation and heat radiation, keep the body continually at nearly the same temperature.

II. FEVERS

If the heat generation goes on too rapidly, or if the heat radiation goes on too slowly, as it would if the skin were too dry, the temperature of the body will rise, and we say the person has a fever. In the treatment of fevers the physician usually tries either to decrease the heat generation in the body, or to increase the heat radiation, and thus reduce the temperature of the body to the normal one.

9. HYGIENE OF RESPIRATION

I. RESPIRATORY MOVEMENTS

THE clothing of the chest and abdomen should be loose enough to enable free movements in respiration. It is probable that one of the most frequent causes of ill health in women is the improper oxidation of tissue as a result (1) of shallow breathing due to improper clothing, and (2) of living much within doors in ill-ventilated houses. No one should allow a day to pass without filling the lungs several times to their greatest capacity. The advantage of these deep inspirations is increased if the lungs are filled with pure, out-of-door air. It is still further increased if the respirations are deep as a result of vigorous exercise out of doors. If one must be confined to the house for most of the time, it is advisable to devote a few minutes two or three times each day to vigorous calisthenics, accompanied by deep breathing, preferably in front of an open window. The air should always pass through the nose, as that is nature's respiratory passage, and is so constructed as to free the air from dust and to warm it before it goes into the air passages.

II. IMPURE AIR

The principal impurity of the air in buildings is carbon dioxide given off from the lungs of the people in the building. It is also given off in large quantities by lamps and gas stoves, and may be given off in small quantities from coal stoves. Another impurity is the dust always found in buildings. Occasionally there may be noxious gases given off from furnaces, or escaping from gas fixtures or from the plumbing. The latter is called sewer gas.

The greatest care should be taken by those who have buildings in charge to insure their absolute freedom from all of these harmful, and sometimes fatal, impurities of the air. Decaying vegetables and stagnant water in cellars are frequently causes of disease, contaminating especially the atmosphere of the building. No such known cause of disease should be tolerated in a building.

III. VENTILATION

Ventilation is a term used to designate the change of air in a building. Every properly constructed building is planned to have an air space for each occupant so large that the air will not have to be rapidly changed in order to be sufficiently pure.

The amount of space allowed for each person occupying a schoolroom during only a few hours in a day is 250 cubic feet. In a room in a dwelling used all day or all night, 300 cubic feet should be allowed, while in a ward in a hospital it is usual to allow 1000 cubic feet for each occupant.

When a room is properly ventilated, the air should seem odorless to one coming in from out of doors. A proper system of ventilation provides for a constant change of air without noticeable drafts. An occasional throwing open of doors and windows for a general rushing in of out-of-door air, and a cooling of the air down several degrees, is an exceedingly clumsy way of ventilating a room. The opening of one window of a room may not permit a sufficient exchange of the air within with that outside, and it is difficult at best to ventilate a house through the windows alone without causing drafts.

Public buildings are usually ventilated through flues in the walls, flues opening near the floor and near the ceiling in each room. An important feature of the ventilation of a dwelling house is the fireplace, with its flue. When the fireplace is open, as it should always be, the dropping of several windows, upstairs and down, an inch at the top will usually afford ample ventilation, without any noticeable drafts.

The presence of illuminating gas, or other gas having a distinct odor, may be at once detected; the most dangerous gas in a building is sewer gas, which has no odor. If sewer gas is present, it is usually suspected by the family physician from the general health of the members of the household, and if an expert examination reveals its presence, the plumbing of the house must be repaired. Fortunately, the escape of sewer gas into a house is not a very frequent occurrence.

The gas that is always present, and always injurious when present in an amount to exceed eight parts in ten thousand, is *carbon dioxide*. As carbon dioxide is odorless, it is necessary to have some simple test to show when it is present in excess of this proportion named above.

Keep on hand a bottle of clear limewater. To test the air in any room to see if it is sufficiently free from carbon dioxide to be wholesome, go into the room, provided with a pint fruit jar full of water, with the bottle of limewater, and with a teaspoon. Pour out the water from the fruit jar, and its place will be taken by the air of the room. Then pour into the fruit jar six teaspoonfuls of the limewater, fasten on the cover of the fruit jar tightly, and shake it vigorously. If there are more than eight parts in ten thousand of carbonic acid present in the room, the limewater will show it by turning a milky color. If there

is a smaller proportion than that, the limewater will not be noticeably affected.

10. EXPERIMENTS

GET about a pound of unslacked lime from a mason or plasterer. Put half of it into a quart fruit jar and fill the jar with water. The lime will slack in the jar, and a portion of the lime will combine with the water to make calcium hydrate, or *limewater*. After one or two days the lime will have settled to the bottom and there will be clear water on top. Pour the clear portion off carefully into another jar or bottle and label it: *Calcium Hydrate or Limewater*.

1. Fill a drinking glass half full of limewater, then take a glass or rubber tube or lemonade straw and blow gently through the tube into the limewater, completely emptying the lungs of air, thus making the air which was in the lungs bubble up through the limewater. Notice the white cloud which gathers in the previously clear limewater.

This white cloud is a precipitate of calcium carbonate which was formed by the carbon dioxide of the breath combining with the calcium of the limewater. This calcium carbonate is the same material of which your chalk crayons are made, and the same material of which marble is composed.

2. Put a piece of candle about an inch long into an empty drinking glass and light it. The flame is at first fed by the oxygen in the glass, but as soon as the oxygen is used up the flame dies. Take out the candle, relight it, and lower it into the glass; it will go out as soon as it gets below the surface of the carbon dioxide which now

fills the glass. Put a sheet of wet paper over the glass to keep the carbon dioxide from mixing with the air. Into another glass of the same size put two tablespoonfuls of limewater. Invert the glass containing the carbon dioxide over the glass containing the limewater; draw out the sheet of paper from between the glasses, and vigorously shake the two glasses, holding them together at the rim. The carbon dioxide has mixed with the limewater and formed the turbid cloud of calcium carbonate.

From these two experiments we find, first, that by the oxidation of a candle, as well as by the oxidation of the tissues of the body, carbon dioxide is formed. Second, we find that the flame of a candle will be extinguished in an atmosphere of carbon dioxide. It is also true that the "flame of life" will be extinguished in a similar atmosphere.

3. Test the air in your schoolroom with a fruit jar as directed above in the text, to see if the ventilation is sufficient. If it is not sufficient, try to devise some means by which the ventilation can be improved without causing direct drafts upon the occupants of the room.

PROBLEMS

1. How many pupils should be seated in a schoolroom 30 feet wide, 40 feet long, and 15 feet high?

2. If a schoolroom is 20 feet wide and 30 feet long, how high should the ceiling be to accommodate 30 pupils?

3. How many individuals may occupy a sleeping room 10 by 15 feet, 8 feet high?

4. How high should a hospital ward be which is 20 feet wide, 40 feet long, to accommodate 10 patients?

11. THE EFFECTS OF NARCOTICS UPON RESPIRATION

I. EFFECTS OF ALCOHOL UPON THE RED BLOOD CORPUSCLES

ALCOHOL acts upon the red blood corpuscles, lessening their power to take oxygen from the air cells of the lungs and carry it to the tissues of the body.¹

The direct effect of the above upon the tissues is, according to Dr. Parker of Chicago, the diminishing of the functional activity of the secreting and excreting structures, causing the blood to accumulate and retain the waste material.

II. RELATION OF ALCOHOL TO ANIMAL HEAT

Dr. Bodländer proved several years ago that about ninety per cent of alcohol taken into the stomach is oxidized, forming carbon dioxide gas and water, and generating heat. He believed that the injury done by alcohol consists in part of the robbing of the other cells of the body of their supply of oxygen, and the rapid formation of carbon dioxide, which acts as a poison until thrown out of the system.

“For the heating of the body it seems that only certain kinds of carbonaceous substances are suitable. The action of alcohol upon the cells tends to cause their degeneration, changing them to fat, and, as it were, makes the cells of the various organs grow prematurely old. Alcohol is, it seems, a most unsuitable substance with which to produce warmth.”²

¹ Allbutt's *System of Medicine*, Vol. III, p. 839.

² *Medical Pioneer*, October, 1896, p. 204, quoting from Pflüger's Archives, Vol. XXXII, p. 399.

Men who use ardent spirits often say that they do so in winter to "keep their bodies warm." No one could make a greater mistake than to suppose that the effect of alcoholic drinks is to warm the body. Many and often repeated experiments upon this question prove that when the liquor is taken in sufficient quantity to make the person feel warm he is really losing body heat through the skin, and the temperature of the body is falling. If a person is exposed to extreme cold for several hours, the temperature of the body may fall so low as to endanger life.¹

We learn from this that the body is not always warm when it feels warm. In the case above mentioned the person feels warm because the skin is kept warm by the blood flowing to it in unusual amounts.

III. RELATION OF ALCOHOL TO LUNG DISEASES

A recent article in the *Medical Times*, quoting from the *Hospital Gazette*, states that the use of alcohol makes a person more liable to pneumonia.

Dr. Delearde says that pneumonia is much more severe in those addicted to the use of alcoholic drinks than in others; that it runs a longer course; that it is often accompanied by violent delirium, followed by prostration,

¹ Professor Brunton, St. Bartholomew Hospital, London. *Lectures on the Action of Medicine*, p. 128. "A party of engineers were surveying in the Sierra Nevadas. They camped at a great height above the sea level, where the air was very cold and they were chilled and uncomfortable. Some of them drank a little whisky and felt less uncomfortable; some of them drank a lot of whisky and went to bed feeling very jolly and comfortable indeed. But in the morning the men who had not taken any whisky got up in good condition; those who had taken a little whisky got up feeling very miserable; the men who had taken a lot of whisky did not get up at all; they were simply frozen to death. They had warmed the surface of their bodies at the expense of their internal organs."

or even unconsciousness, and that in those who recover at all, there frequently occur abscesses in the liver or in other organs.

Dr. Legendre, a Paris physician, has recently published, for public distribution, a leaflet in which he says: "Alcohol is a frequent cause of consumption by its power of weakening the lungs. Every year we see patients who attend the hospital for alcoholism come back after a period to be treated for consumption."¹

An American medical writer² points out the reason why the use of alcohol makes one liable to consumption. He mentions the use of alcohol among various other things which cause the natural vital resistance of the healthy body to be impaired. Among those other things mentioned with alcohol, which produce this impairment of vital resistance, are: "Living in overcrowded, ill-ventilated houses, on damp soils, or insufficient clothing and outdoor exercise."

IV. INFLUENCE OF TOBACCO UPON THE RESPIRATORY SYSTEM

"Nicotine stimulates secretion in general, as is illustrated by its influence upon the mucous glands of the mouth. This overstimulation of the mucous membrane would naturally lead to the development of catarrhal affections."³

REVIEW OF THE RESPIRATION

1. Every living thing, both plant and animal, needs oxygen. The process of furnishing oxygen for the tissues of a plant or animal is called respiration.

¹ London *Lancet*.

² See *Journal of American Medical Association*, October 23, 1897, p. 847.

³ Dr. J. W. Seaver, Yale University, in *Journal of Inebriety*.

2. The *Inspiration* and *Expiration* of air to and from the lungs are together called *External Respiration*; while the exchange of oxygen for carbon dioxide in the tissues is called *Internal Respiration*.

3. The *Air passages* are: the *nasal* passage, the *pharynx*, the *larynx*, the *windpipe*, the *bronchi*, the *bronchioles*, and the *air cells*.

4. The *Air passages*, below the *larynx*, are lined with *ciliated* cells. The cilia carry the mucus and particles of dust that may enter the lungs with the air up to the *larynx*, where it gives one a tickling sensation and is coughed up.

5. The *Diaphragm* is the principal muscle of respiration. The *intercostal muscles* and the *abdominal muscles* assist.

6. The movements of the chest and abdomen should not be interfered with by clothing that fits too tightly.

7. Describe: Coughing, sneezing, yawning, hiccoughing, sighing, crying, laughing, and sobbing.

8. How many vowels has the English language? How are these vowel sounds produced and how modified? How many consonant sounds in English? How are consonants classified and how are they produced?

9. What are the characteristics of a cultured and refined voice? All people may cultivate refinement in the voice. One is judged more by the voice and the language than by anything else when he first meets a stranger. First impressions are very valuable when favorable, and very damaging and difficult to remove when unfavorable.

10. The air is composed chiefly of *Nitrogen* and *Oxygen*, with a little *Carbon dioxide gas* and *Water vapor*.

11. In the lungs the air gives up about one fourth of its oxygen, receives carbon dioxide in almost an equal quantity, and receives water vapor, and also a small amount of organic matter.

12. *Oxygen* is carried by the red blood cells, while carbon dioxide is carried mostly by the plasma.

13. The heat of the body is produced by the oxidation of its tissues.

14. The heat of the body is regulated partly by changes in the rate of oxidation and partly by changes in the rate of the giving up of heat by the skin. In a similar way one changes the temperature of a house by changing the rate at which the fire in the furnace burns, or by opening or closing windows. Both of these methods of regulating may be changed at the same time.

15. One should often breathe deeply to expand and develop the

lungs. One should breathe pure air either out of doors or in well-ventilated rooms.

16. *Alcohol, though oxidized in the body, lowers the temperature, because more heat is lost from the skin than is produced by the oxidation of the alcohol. Explain this.*

17. *The use of alcohol weakens the lungs and makes one more liable to lung diseases than he would be if he abstained from it.*

18. The use of tobacco is likely to cause or to increase the tendency to catarrh.

CHAPTER VIII.—HOW THE FOOD IS USED IN THE BODY

THE chapter on nutrition described foods, and told how they were digested in the alimentary canal, but did not tell how the foods were used by the body after they were digested.

The object of this chapter is to show first, how the digested food is absorbed from the alimentary canal; and second, how it is built up into living tissue in the body; and third, under what conditions it is oxidized, and what is formed as a result of the oxidation. Before beginning these subjects, let us review the chapter on nutrition by answering the following questions:—

1. How many and what kinds of food are there, or how many kinds of food stuffs?

2. What is the name of the digestive fluid secreted into the mouth?

3. On what class of foods does this fluid act, and what changes does it produce?

4. What digestive fluid is secreted into the stomach?

5. On what kind of food does it act?

6. What change does it produce upon this food?

7. What digestive fluids are secreted into the small intestine?

8. What kinds of food are digested in the small intestine?

9. What name is given to the partly digested food that passes through the stomach into the small intestine?

10. To what form are all the starches and sugars finally reduced by the digestive process?

11. To what form are all proteid foods reduced by the digestive process?

12. To what forms are the fats reduced by the digestive process?

1. HOW THE DIGESTED FOOD IS ABSORBED FROM THE ALIMENTARY CANAL

AFTER the digestive process has changed the starches and sugars to dextrose, the proteids to peptones, and the fats to soap and emulsion, the food is still no part of the body. It is inside of the body, but in a closed tube, and until it gets through the walls of the tube it is not part of the body.

The interior lining of the intestines is thrown up in folds which, when magnified, look like fingers projecting into the intestines (Fig. 44). These are the villi which absorb the food into the system. If we magnify the villus very much, we see the whole surface is covered with absorbing cells. They are not open, but the chyme, or digested food, passes through the thin cell walls. If we cut a thin slice across the villus (Fig. 45), we see the absorbing cells leading toward the interior, where there are many blood vessels, and beyond which, in the very center of the villus, is a tube called a lacteal, which you know is an intestinal lymphatic.

Some of the nourishment absorbed by the cell is taken up by the blood vessels, and some goes into the lacteal which carries it to a large duct, called the thoracic duct, which goes up the left side of the center of the body to the neck, where it empties into the jugular vein (Fig. 38,

p. 150). The lacteals take up the fats and part of the peptones.

The rest of the nourishment, the sugars and a part of the peptones, is taken up by the blood vessels which unite to form the portal vein, and is carried by the blood to the liver.

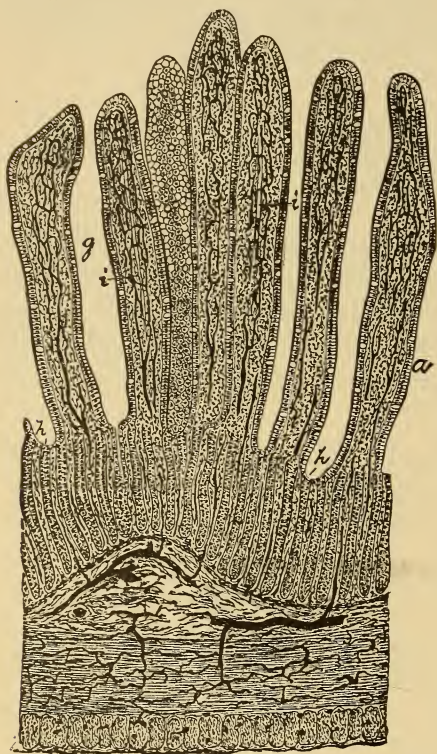


FIG. 44. — Showing the villi or fingerlike projections of the mucous membrane of the small intestine. In the third one from the right and second from left notice the central lacteal (*i*). The intestinal glands are shown at (*h*). The heavy black lines are blood vessels. [Piersol.]

When the foods are passing through the absorbing cells of the villus, a change is made in some of them by the absorbing cells. The peptone absorbed from the alimentary canal is sent into the blood vessels, not as peptone, but as blood albumen, in which form it accumulates until it is taken up from the capillaries by the living tissues. The fats are taken up from the alimentary canal by the absorbing cells, and turned into the lacteals in minute globules. These globules floating in the lymph

plasma give it the milky appearance. The sugar absorbed is turned into the blood vessels unchanged, and so passes to the liver as sugar.

2. HOW DIGESTED FOOD IS BUILT UP INTO LIVING TISSUE IN THE BODY

IN the previous lesson we traced the absorbed food stuffs directly into the blood of the portal vein or indirectly into the veins by way of the lacteals and the thoracic duct, so that the absorbed food at once becomes

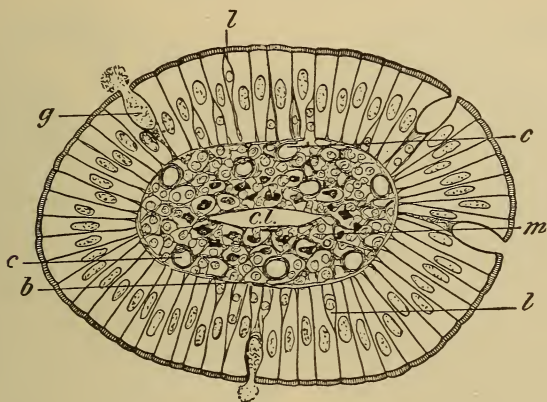


FIG. 45. — Showing a cross slice of a villus. Note the central lacteal (*c.l.*), the blood capillaries (*c*), the absorbing cells all around the villus, the mucus-forming cells at (*g*). [Schaefer.]

a part of the circulating fluids of the body; but it does not become living tissue until it is absorbed into the living cells of the tissue.

Let us first trace the dextrose. Sooner or later all the dextrose absorbed circulates through the liver. Figure 46 shows the general shape of the liver as it looks from below. You will notice that the portal vein divided, sending a branch to each lobe of the liver. Notice the liver artery which brings oxygenated blood from the lungs, so that there are two streams of blood passing to the liver, one from the intestines, and one from the lungs, while

there is one stream of blood going away from the liver by way of the vena cava.

The gall bladder serves as a reservoir to collect a portion of the bile which is from time to time sent out through the bile duct into the intestines. Now if a very thin slice were made through the liver, and this slice examined under a high power microscope, one would find it divided

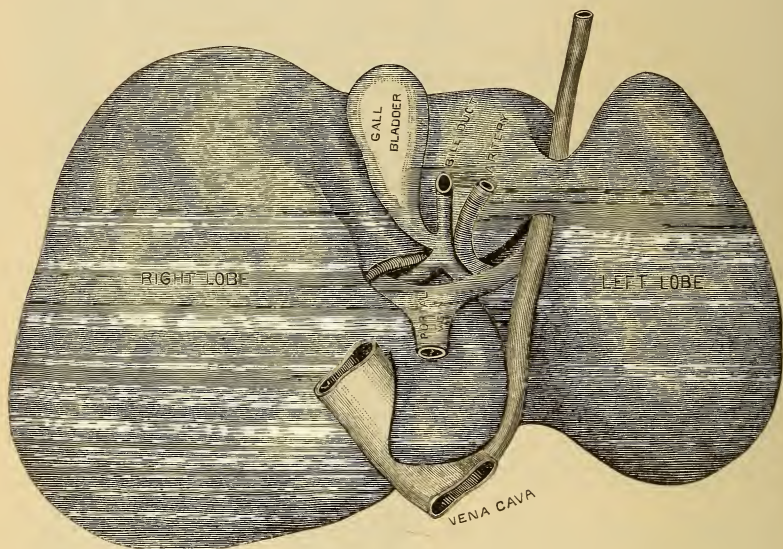


FIG. 46. — Under surface of the liver. [Tracy.]

into little five-sided or six-sided areas called lobules (Fig. 47).

The blood of the portal vein passes through a network of veins marked *p* in the figure, forming a network of venules between the lobules. From this network of venules, innumerable fine capillaries pass toward the center of each lobule, gathering there into a venous trunk,

which passes out of the lobule and joins others on the way to the vena cava.

While the blood is passing through the capillaries, an opportunity is given for the active gland cells of the liver (which are shown in two places in the lobules only, though really they fill all the space) to absorb the dextrose from the blood. What these cells do with the dextrose

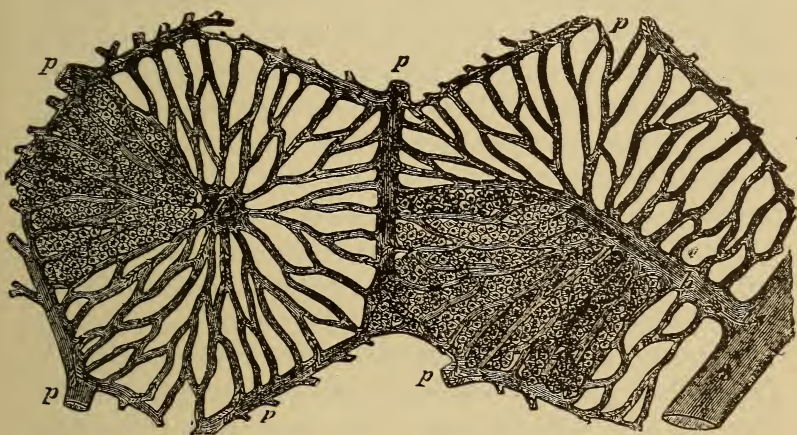


FIG. 47. — Diagram of two liver lobules. Note the branches of the portal vein (marked *p*), from which a system of capillaries pass in to the middle of the lobules. In the lobule at the right is shown how the blood gets out of the lobule and joins a branch of the liver vein on its way to the vena cava. Note the liver cells between the capillaries. The liver cells do the work of the liver. [Landois.]

is one of the most wonderful processes; *they change it back to starch*, so that food that was taken in the form of starch is changed to sugar, and then back to starch in the body. This liver starch is called animal starch.

The liver acts as a storehouse for this kind of food, so that after a meal where considerable starch or sugar has been eaten, the liver will be filled with starch, which is thus stored away to be given out a little at a time until

the next meal. When this food is needed by the system, which will probably occur within two hours after it is stored in the liver, the liver changes the starch back to sugar, and the liver cells throw this sugar out into the capillaries again, and from the capillaries it passes into the liver vein, and from the liver vein into the vena cava, which carries it to the right side of the heart, whence it goes to the lungs, and is sent to the left ventricle. The left ventricle sends it through the arterial system to the tissues, where, as a part of the plasma, it oozes through the capillaries and around the cells of the tissues.

Now these cells use more sugar than anything else. All the living cells of our body use sugar ; so the sugar is absorbed from the plasma and taken into the living cells, where it becomes a part of their protoplasm, that is, it is assimilated, but here it is soon oxidized to generate the energy which the cells must use in their work.

The fat which was thrown into the venous system in the form of minute globules, floats along in the veins into the heart, through the lungs, and then by the way of the ventricle into the arteries and capillaries, where it comes in contact with the living cells of the various tissues. It is taken up from the plasma by these cells and either built into living protoplasm or oxidized within the protoplasm to yield energy, or it may be deposited within the protoplasm in the form of fat globules.

If one eats more starch and fats than are required for the energy of heat and motion, this material is usually deposited in the savings bank of the system, because the system is very economical, never wasting any food that it has taken the trouble to digest. The savings bank of the system is located in the connective tissue, and the savings are deposited in the form of fat. If there is much

saved, the individual may become quite "fleshy," as we say.

The proteid matter absorbed as peptone and changed to blood proteid, continues to accumulate in the blood until it is absorbed by the living cells and either built up into living protoplasm or oxidized within the cell protoplasm to yield energy.

Remember: (1) Food taken into the alimentary canal must usually be digested before it is absorbed. Such substances as water, salt, and certain kinds of sugar do not need digestion, but are absorbed in the form in which they are eaten. (2) *Absorption* is the taking up of substances by the body; for example, oil may be absorbed by the skin, oxygen by the lungs, and sugar, fats, water, peptones, salts, etc., by the lining of the intestine. (3) *Assimilation* is building up of absorbed food into the living tissue of the body. (4) Foods do not yield their energy to the body until they are oxidized. *Oxidation* is the reverse of assimilation. Assimilation is a building-up process, while oxidation is a pulling-down process. Assimilation requires energy to bring it about, while oxidation yields energy. Motion, heat, and light are kinds of energy.

3. THE GENERATION OF LIFE ENERGY

THE first lesson in nutrition tells why we eat. You remember that we eat food for the energy that it contains, and the whole processes of digestion, and circulation, and respiration all lead up to the generation of this energy, to obtain which the food was taken. We traced the food, which is the fuel of the body, into the living cells; we have traced the oxygen into the living cells. The next

step is the oxidation of this body fuel and the generation of life energy.

Muscle tissues are by far the larger part of the active tissues, so that we are prepared to expect that most of the energy liberated by the body will be muscular energy. One usually thinks of muscular energy as energy of motion, because we use our muscles in our movements; but the energy of motion is not more important than the heat energy which the muscles generate. The muscles generate motion during only a small part of the time, but they generate the energy of heat continually, never stopping from the day of birth to the day of death, nor any single hour between these days.

The glands of the body work only a part of the time, and some of the work which the glands do generates heat, while other parts of their work require energy from other sources.

The nervous system generates a kind of energy peculiar to itself, which seems to be similar in many respects to electricity. There is some heat, also, generated in the nervous system.

Where fuel is being oxidized, or burned, we usually find smoke, ashes, and gases. The smoke is composed of unburned carbon and water; the ashes represent the mineral matter of the fuel; while the gases are represented, for the most part, by carbon dioxide. The oxidation in the body is similar to the oxidation in a locomotive in many respects, and there are waste matters resulting from body oxidation, as there are waste matters resulting from fuel oxidation. Water is formed; carbon dioxide is formed; and there are certain substances which may represent the ashes, substances which contain nitrogen. These substances are as poisonous to the flame of

life, if they are allowed to collect in the body, as the carbon dioxide which collects in the drinking glass is poisonous to the candle flame.

If the unoxidized nitrogenous substances are not thrown out of the system, they will clog it up and destroy its proper action, just as surely as the cinders and ashes of the locomotive would put out the fire if they were not raked out.

CHAPTER IX. — HOW THE WASTE MATERIALS ARE THROWN OUT OF THE BODY

IN the previous lesson we learned that active cells are constantly forming products of oxidation which are poisonous to the system, and which, if not thrown out, would very soon destroy the life. These products can be grouped into three classes: (1) carbon dioxide; (2) water; (3) nitrogenous substances and mineral salts.

The carbon dioxide is carried to the lungs by the blood, and thrown out of the system in the way described under Respiration. The water that is formed in the system, together with large portions of that which is taken in as drink, is given off from the system in two different ways, besides that which leaves by way of the lungs and intestines. First, it is given off by the skin in the form of perspiration. There are innumerable fine pores, those lining the palm of the hand being large enough to be seen with a common magnifying glass. These pores, which cover the whole surface of the body, are the openings of minute glands which lie in the skin, and whose work it is to form the sweat or perspiration. These glands are called the sweat glands.

When we were studying about animal heat, we found that the temperature of the body was controlled in part by the rate at which water was poured out on the skin in the form of perspiration. The work which these sweat glands do in helping to regulate temperature is very much more important than the work which they do in

throwing out the water of the system, because the water can go out of the lungs, intestines, and kidneys, but there is no tissue or organ that can, in man, take the place of the skin in the regulation of the temperature.

Let us, then, remember that of two kinds of work which the skin does, the heat-regulation part is very much more important than the work which it does in ridding the system of a part of the water.

But the most important organs for throwing out waste materials are the kidneys.

1. EXCRETION BY THE KIDNEYS

THE process of throwing out waste material from the body is called excretion. We have seen, from what has just been said, that the lungs, and skin, and intestines are all organs of excretion, or *excretory organs*. The kidneys differ from other excretory organs in the fact that they have no other function, but devote their whole time and energy to the work of separating out from the blood waste substances which, if retained in the body, would soon cause convulsions and death.

The kidneys are two in number, and about long enough to reach across the palm of the hand. They are located in the back part of the abdominal cavity, back of the thin membrane which lines the cavity, and which holds them in place. They are located about opposite the small of the back, one on either side of the spinal column. Each receives a large branch from the abdominal aorta, and each gives off a large branch which passes to the inferior vena cava (Fig. 48). From each kidney a tube passes down to the bladder, which is located in the lower part of the abdominal cavity, in front.

The kidney is a glandular organ, and the arterial blood, after passing into the kidney, is distributed in fine arterioles to an innumerable number of little capillary tufts,

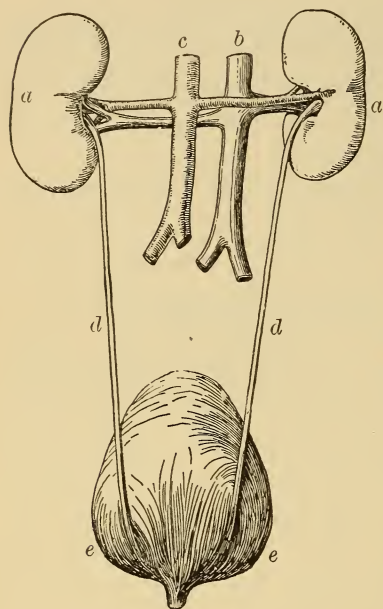


FIG. 48. — The kidneys and bladder as they would look if viewed from behind. *a*, kidneys; *b*, abdominal aorta; *c*, vena cava; *d*, ureters, tubes to carry urine to the bladder; *e*, bladder.

where the excess of water of the blood is filtered out, and passes along a little glandular tube, which is surrounded by a network of capillaries. The cells of this glandular tube take out from the blood in the capillaries all of the nitrogenous waste matter and pour it into the canal of the tube, where it is washed along by the water into a common receptacle in that part of the kidneys where the blood vessels enter, and from this common receptacle it flows down the little drainage tube to the bladder, where it collects, and from which it is from time to time given off.

2. THE HYGIENE OF THE LIVER AND KIDNEYS

I. HOW TO TAKE CARE OF THE LIVER

It is not easy for a person to tell the condition of his liver. One of the functions of the liver is to form bile. When the liver is in a condition to form bile properly, it

is usually in a condition to do the rest of its work. When the bile is improperly formed, or formed in too small quantities, a person becomes constipated, and that which passes the bowels is too light in color. To guard against this condition, which is a very serious one, and which always leads to the derangement of other functions of the body, one should avoid overeating and should take plenty of exercise in the open air. If, through carelessness, the system gets in the condition above mentioned, one should consult a physician for more extended advice than can be given in this brief book.

II. HOW TO TAKE CARE OF THE KIDNEYS

The urine should be a light yellow color, and perfectly clear, and no sediment should collect if it stands in a receptacle for twenty-four hours. The kidneys are injured by overwork; and, as the principal work of the kidneys is to excrete nitrogenous waste matter, it is easy to see that the eating of too much nitrogenous food, or proteid food, will result in the kidneys being overworked.

The best rule to follow, if one wishes to keep these organs in healthy condition, is to eat sparingly of meat, and drink plenty of water. Most people drink too little water; few people drink too much water.

If the urine becomes unusually dark in color, or if there should be a reddish sediment when it stands in a receptacle, one should drink all the water he can for a few days. Lemonade is wholesome for these organs which eliminate the waste materials from the body. The lemonade should be taken with little sugar, and not too strong, and may be taken in large quantities, especially in summer.

III. THE EFFECTS OF ALCOHOL UPON THE LIVER AND KIDNEYS

Dr. Wilkins¹ says that the coloring matter of the bile cannot be properly oxidized in the presence of alcohol, and that the work of the liver must be deranged while alcohol is passing into the system through that organ.

Dr. McMichael² says, "Alcohol produces disease of the liver and of the kidneys because these glands are most concerned in the throwing out of any poison, and are always, until they are deranged in structure, engaged in removing it from the body." He says that the disease almost universally caused in the liver by alcohol, is one in which the connective tissue framework of the liver increases, taking the place of the liver cells, until the liver is no longer able to perform its function.

The kidneys may undergo a change similar to that of the liver when alcohol is used, even in moderate amounts, for a long period.

Such profound changes in organs whose work is so important to the system, are naturally accompanied by derangements of the general health, and at last are frequent causes of death.

¹ *New York Medical Journal*, September 22, 1894.

² *Dietetic and Hygienic Gazette*, May, 1897, p. 279.

CHAPTER X. — THE SKIN — HOW IT IS MADE, AND WHAT IT DOES — HOW TO TAKE CARE OF IT

THE skin has been mentioned several times in the preceding lessons. We have found that it is a most important organ for the regulation of the temperature, and that it takes a part in the throwing out of waste materials from the body; but its most important work has not yet been mentioned. You remember that the little plant, described in the first lessons of this book, was provided with a thin, transparent skin; you remember that the bark of a tree was called its skin, and you know that the bark of a tree protects from injury the sensitive tissues which lie beneath it.

In a similar way, the skin of animals is *an organ of protection*; and although this organ may perform, or assist in performing, several other functions, this one is the most important of all. The skin is made in such a way as to adapt it especially for its principal function, protection.

1. HOW THE SKIN IS MADE

THE skin is composed of two layers; one of these is composed of living tissues, and the other of nonliving tissues. Figure 49 shows the living layer of skin at *Dm*. This layer, which is called the dermis, or true skin, is composed of a network of fibers of connective tissue, within which lie the *blood vessels* and *lymphatics*, which

bring the nourishment to the tissues; the *nerves*, which make the skin sensitive to touch and to changes of temperature; the *oil glands*, which pour their oil out on the surface

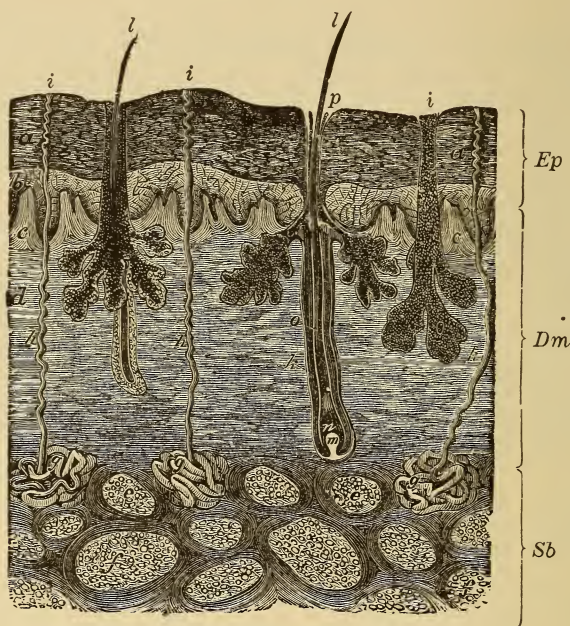


FIG. 49. — Vertical section of the skin, magnified: *a*, scarfskin; *b*, pigment cells; *c*, papillæ; *Dm*, true skin; *e, f*, fat cells; *g*, sweat glands; *h*, outlets of sweat glands; *i*, their openings on the surface of the skin; *k*, hair follicle; *l*, hairs projecting from the skin; *m*, hair papilla; *n*, hair bulb; *o*, root of hair; *p*, openings of oil glands; *Ep*, epidermis; *Sb*, subcutaneous connective tissue.

face of the skin; the *hair follicles* and the ducts of the *sweat glands*.

This living part of the skin is very elastic, adapting itself perfectly to the curves of the body and the bending of the joints. Notice in the figure that the hairs have their roots in this true skin. Each hair grows from a papilla (Fig. 49, *m*); this papilla is provided with a nerve

fiber and a tuft of capillaries. From the surface of this papilla the hair grows, thus pushing the hair out of the follicle, so that the hair becomes longer and longer as it grows at the papilla.

The oil glands are located on either side of the hair follicle, and pour their secretion into the follicles beside the hair. This passes along through the epidermis, and pours out upon its surface around the hair. Notice that the surface of the true skin is rough, the prominences reminding one of a mountain range. These prominences are called papillæ. Within every papilla there are either nerve endings or tufts of capillaries. The nerve endings make the surface of the skin sensitive, and the capillaries, besides bringing nourishment, bring the blood very near to the surface, where it may be cooled or where it may warm the surface.

The papillæ of the true skin are not exposed to the air, but are covered with a deep *protective layer*, called the *cuticle*, or the *epidermis*. The cuticle is formed by the true skin; the cells of the cuticle which lie next to the true skin are living cells. They draw their nourishment from the true skin, and keep dividing and forming new cells. These new cells are pushed out from the true skin until they get so far from the blood and lymph of the true skin that they can no longer get nourishment, and so they die. The dark line between *a* and *b* in the figure shows where this change takes place.

That portion of the cuticle that is darker in the figure represents the dead scarfskin. Now as these cells are constantly forming on the surface of the true skin, the scarfskin would become enormously thick if its surface layers were not rubbed off by friction, such as that of the clothing. The cuticle is the protective tissue of the

whole body ; the dead cells of its surface are not sensitive. Pressure upon its surface is felt because it presses through the epidermis upon the sensitive papillæ beneath.

The cuticle alone is not sufficient protection for the body, so most surfaces of the bodies of the mammals are provided with hair. Notice the back of your arm, and you will see great numbers of fine hairs growing ; these hairs protect the surface of the skin. They are especially thick upon the head, and when man lived in a savage state the matted hair was usually the only protection for the head.

The tips of the fingers and toes are protected with nails. The papilla through which the hair grows corresponds to a papilla at the surface of the true skin, and a hair which grows from the surface of the hair papilla corresponds to the cuticle growing from the surface of the papilla of the true skin, so that we can see that the hair is modified cuticle. In a similar way the nails represent modified cuticle, and grow from the surface of the modified papillæ. The teeth grow from modified papillæ, and also represent modified cuticle. The same thing is true of the feathers of birds, the scales of fishes and reptiles, and the hoofs, horns, and claws of the lower mammals. If you think of the use to which these animals put these structures, you will see that they are all used for protection except the teeth, which, although used somewhat for defense, may also be used for other purposes.

The work of the skin is first of all protection. In most mammals the protection against extreme changes of temperature is provided for by a thick coat of hair or fur. In birds the coat of feathers performs a similar service. At first it may seem that the horse's coat could not be

quickly changed from a thin one to a thick one, but that he must wait for the spring shedding of his thick winter coat in order to have a summer coat, which is thickened up by a new growth of hair in the fall for winter; but the horse may change the thickness of his coat in a few minutes. If you will look at the hairs on the back of your arm you will see that they do not come straight out of the skin, but they come out obliquely, and all that are near together lie in the same direction. Each hair has a little muscle attached to the end of its follicle, as shown in

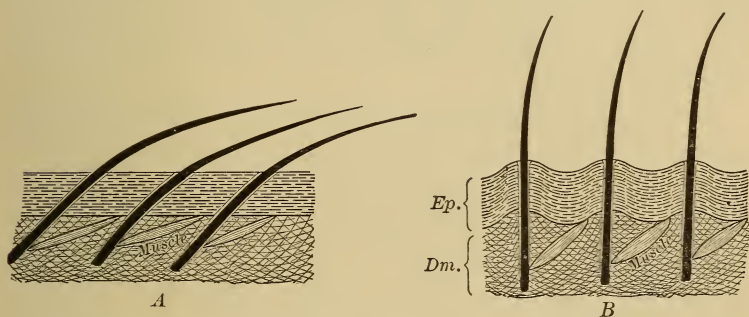


FIG. 50.—Diagram showing at *A* the hairs lying down and the muscles at rest. At *B* the muscles have contracted, pulling the hairs up straight, thus making the coat much thicker and warmer.

Figure 50. When the skin is warm, the hair lies down as shown in position *A*, that makes the whole coat of hair compact. When the cold strikes the skin, the muscle of each hair contracts and draws it up so that it stands perpendicular to the skin. This makes the coat of hair very much thicker than it was before and keeps the animal correspondingly warmer. In man the hair which covers the general surface of the body is so thin and short that it cannot keep the body warm, but the muscles contract just the same and pull the hairs up, pushing up a little point

of skin about each hair. This appearance of the skin is called goose flesh.

The cuticle protects the delicate dermis from friction and pressure. If the friction and pressure are severe, the cuticle becomes thicker and more dense than it is over the general surface of the body. Look at the palms of your hands and see if you have not little calluses. The cuticle on the bottom of the foot is much thicker than on the top of the foot. If the shoe does not fit perfectly, a thickened callus may form where it presses or rubs the foot. If this thickened callus becomes hard it may make the dermis beneath sensitive and sore. We call this condition a *corn*.

Next to the function of *protection*, the most important work of the skin is the *regulation of temperature* mentioned above, and next is the part which the nerves of the skin, together with modified portions of the skin, play in warning the system of danger or of changes. This function of the nerves of the skin is called *sensation*. Another but comparatively unimportant function of the skin is *excretion*.

2. THE HYGIENE OF THE SKIN

I. CLEANLINESS

THE oil which is poured out upon the surface of the skin is perfectly clean, but it very readily collects dust and other impurities of the air. The scarfskin is continually being shed in minute scales composed of a few thin cells. If these were not removed from the surface they would soon collect in sufficient quantities to be visible as minute scales. The most important source of uncleanness of the skin is the perspiration which is constantly being poured out upon the surface of the skin.

Figure 49 shows the little coiled sweat gland in the loose tissue below the true skin. This sweat gland takes up water and various other substances from the blood, and pours them out upon the surface of the skin.

Sometimes we are not conscious of the perspiration because it does not make the surface wet, that is, because it escapes in the form of vapor from the pores ; that kind is called *insensible perspiration*, but when it comes in large enough quantities to be condensed, and make the skin moist, then we call it *sensible perspiration*. The water of the perspiration evaporates to cool the body, but the salt and other solids remain upon the surface of the skin. This, mixed with the oil, the little scales of scarfskin, and the dust collected from the atmosphere, will in a very short time make the surface of the body unclean.

A *general bath*, in which use is made of soft water and soap, followed by thorough rubbing with a coarse towel, is a most efficient method for insuring the cleanliness of the skin. For persons in the ordinary occupations a general bath such as that described is not necessary oftener than once or twice a week ; if soap is used oftener, it is likely to make the skin dry and rough ; if a warm bath is taken oftener, it is likely to relax the skin and make the person take cold easily. A general rule for the use of soap and water for cleansing the body is : use it just as freely and just as frequently as is necessary to keep the body clean ; the hands may need it several times a day ; other portions of the body may not need it oftener than once a week.

II. THE MORNING BATH

The warm water cleansing bath, because of its relaxing effect, may best be taken in the evening, especially during

the cooler seasons of the year, but the cold water tonic bath may best be taken in the morning. A tonic bath may be taken either as a plunge bath, as a shower bath, or as a sponge bath. In any case the surface of the body should be wet only for a few moments in water of varying temperature from tepid to cold, and the wetting should be followed by a vigorous rubbing with a coarse towel, and the rubbing continued until the whole surface of the body is red and glowing. Instead of making one take cold more easily, this treatment fortifies one against the feeling of cold or taking cold. It takes a very strong constitution to stand a cold plunge bath ; even a cold shower, lasting but a moment, is not advisable for a weak constitution unless the glow comes quickly. The safest tonic bath for a person not in vigorous health is a cold sponge bath on one portion of the body at a time ; each portion in turn being exposed, sponged, and rubbed until aglow.

III. CLOTHING

Life in the changeable climate of the temperate zone makes it necessary for man to have some other protection than that which Nature provides him. Besides this prime *necessity*, there is the *inclination* on the part of all civilized human beings to wear clothing. Primitive man dressed in the skins of animals ; in the colder climates the overcoat made from the pelts of animals is the best protection against the low temperature.

Clothing is made mostly from wool, cotton, silk, linen, leather, and fur. A fundamental rule for the clothing of the body is, *clothe the body so as to make it comfortable*. To be comfortable the clothing must fit the body closely enough to conform readily to all of its move-

ments. Among these body movements must be mentioned first, the respiratory movements ; no person should wear clothing so close about the waist as to hinder in any way the freest movements of respiration. The movements of the arms should be perfectly free and unhampered by the clothing.

The shoes should not be so tight that one cannot move his toes ; if this rule is not observed the toes will become distorted and covered with corns. Because of the perspiration which is constantly going on and the shedding of the scarfskin, garments that are worn next to the skin in the daytime should be removed at night.

IV. THE INFLUENCE OF ALCOHOL UPON THE SKIN

As already stated in a previous lesson, alcohol dilates the arterioles and capillaries of the skin. If alcohol be used in comparatively small amounts for a long period of time, the capillaries of the skin become permanently dilated, thus giving the skin, especially of the face, a very red appearance, and the little dilated capillaries may be seen running their crooked course just beneath the surface of the skin. When the skin becomes thus changed, it cannot properly perform its portion of the work of excretion, and so the kidneys have to do a portion of the work which the skin ought to do, and thus they become overworked.

3. THE SKIN AS AN ORGAN OF GENERAL SENSATION

THE nerves of the skin have been mentioned. Most of the nerve endings are sensory nerves, whose work it is to bring to the brain messages announcing the condition

of the skin or the condition about the skin. Figure 51 shows a thin slice of the true skin, with four papillæ on its surface ; two of these papillæ have capillary loops, and are therefore called *vascular papillæ*, while two of them have curious little bulb-shaped nerve endings, which are organs of the feeling, or tactile corpuscles, and so the papillæ which have these corpuscles are called *tactile papillæ*.

There are other kinds of nerve endings in the skin. Some nerves end in fine fibrils, which pass up into the lower layer of the cuticle, but all these nerves bring sensation to the brain, and are therefore called *sensory nerves*. All parts of the skin are sensitive to touch and to changes of temperature, though some parts of it are more sensitive than others. The finger tips and the lips and tongue are more sensitive to touch than any other parts of the skin. The reason why these portions of the body are more sensitive to touch is because they have been most used, and, therefore, most developed. Because the senses of touch and of temperature are possessed by all parts of the skin, these senses are called *general senses*. A *special sense* is one which possesses a special organ.

Taste, smell, hearing, and sight, possessing special organs in the tongue, nose, ears, and eyes, are called special senses ; while touch, temperature sense, and the sense of position of the body, are general senses. *There are, therefore, four special senses and three general senses.*

I. THE TACTILE SENSE

How lightly can you touch the tip of one of the hairs on the back of your hand or arm without feeling it ? How small a piece of match stick can you drop upon

the back of the hand, from the distance of two inches above the back of the hand and feel it? If you have a pair of draughtsman's compasses, or dividers, or a pair of sharp-pointed scissors, see how close together you can hold the points and feel them as two points when they touch the skin. At the finger tips, one can feel them as two points at a distance of less than an eighth of an inch.

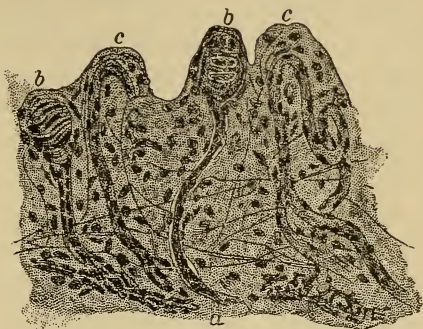


FIG. 51. — *a*, nerve fiber; *b*, tactile papillæ, containing a tactile corpuscle; *c*, vascular papillæ. [After Benda.]

How far apart must they be to feel them as two points on the back of the hand, on the palm of the hand, on the lips, on the cheek, on the throat, on the back of the neck, on the forehead? When blindfolded, how much can you tell, by feeling alone, about an object which may be handed to you?

II. THE TEMPERATURE SENSE

Take a lead pencil which has been cooled in water or in cold air, and move the lead lightly over the back of the hand. Sometimes it will feel cold, and sometimes you have no temperature feeling at all. You will merely feel the lead moving over the hand. If you were to warm the lead by dipping the pencil into warm water, and move it similarly over the back of the hand, you would find that sometimes it would feel warm, and that sometimes you would have no sensation of temperature from this warm lead. From this we learn that the skin is divided into

little areas, some of which are sensitive to cold, and some of which are sensitive to heat, while there are still other areas sensitive to neither cold nor heat. By cold and heat as used here, we mean, of course, substances colder than the skin or warmer than the skin ; because anything that is colder than the skin will feel cold, while anything warmer than the skin will feel warm. A thing which may feel cool sometimes may feel warm at other times, though at the same temperature. For example, if one has three dishes of water standing upon a table, the one at the right hand having cold water, the one at the left, warm water, and the one between the two, tepid water ; if he holds the right hand in the cold water, and the left hand in the warm water, for one or two minutes, and then takes the hands out and places them both in the tepid water, it will feel cold to the left hand and warm to the right hand.

The temperature sense warns the animal of the changes of temperature in the air or water surrounding it, so that he may adapt himself to the change. A part of the adaptation which the animal makes is an unconscious one, made through the sympathetic nervous system, and consists of the withdrawal of the blood from the surface when cold air first strikes the body, and a raising of the hair on end, as described above.

III. THE SENSE OF POSITION

If one were blindfolded and laid upon a table, he could easily tell if the table were lifted or tipped a little in one direction or another ; he could easily tell the direction, and he might even tell the amount, unless the movements were very, very slow. One can walk with the eyes shut, or blindfolded, and maintain the erect position when rid-

ing a bicycle. Though we do all these with the greatest ease, it is really a most difficult thing to do, if one were to stop to think about it, and something that takes a little child nearly as long to learn as to learn to read.

Sensations are carried to the brain from the various parts of the skin. If one is standing or walking, pressure on the soles of the feet will tell in which direction the body is swinging. On whatever part of the body one rests, the skin from that part sends messages to the brain, which enables one to tell the position of the body, or changes in the position. The most important organ for sending messages to the brain regarding the position of the body is located within the internal ear. Through the aid of this organ, the brain knows of all movements of the head, whether from side to side, or forward and back, as well as all movements of the whole body through space, or the turning of the body.

REVIEW OF THE SKIN AND THE GENERAL SENSES

1. The skin is composed of the dead *cuticle* and the living *dermis*. The *dermis* contains *blood vessels*, *nerves*, *oil glands*, *hair follicles*, and its surface is covered with innumerable fine projections called *papillæ*.

2. The *cuticle* not having life is also without feeling. Its work is to *protect* the sensitive tissues which lie beneath it. The *oil* from the oil glands keeps the skin soft and protects it against the absorption of water. The *hair*, or the *feathers*, *scales*, or *plates*, are modified cuticle and serve for protection. *Nails*, *horns*, and *hoofs* are also modified cuticle and serve for protection.

3. The skin helps to regulate the temperature of the body by the perspiration.

4. Because of the secretion of oil and of perspiration by the skin, this organ becomes soiled and must be cleansed with warm water and soap.

5. A tonic morning bath with cool or even cold water followed by

brisk rubbing until the surface of the body is red and warm, is an excellent hygienic custom.

6. *Clothe the body in such a manner as to make it comfortable.*

7. If alcohol is used in moderate quantities for a long period of time, the capillaries become permanently dilated, thus giving the skin a permanent red color.

8. There are three *general senses* and four *special senses*. The general senses are: Touch, or the *tactile sense*, the *temperature sense*, and the *sense of position of the body*.

9. How may one test the tactile sense? Where is this sense most acute? Is it more acute in some persons than in others?

10. How may one test the temperature sense? Why are animals provided with this sense? How does the horse adapt himself to a sudden change in the temperature from warm to cold? How does man adapt himself under similar conditions?

11. How is the brain made conscious of the position of the body when one is standing, sitting, or lying? Of what use is this sense?

CHAPTER XI. — THE SPECIAL SENSES — HOW ONE KNOWS WHAT IS GOING ON ABOUT HIM

THE preceding lesson described the general senses, which are so called because they do not possess a special organ. The special senses, on the other hand, are so called because the sensation is received by a special organ, which has no other function, and which is specially fitted for that particular function.

1. TASTE AND SMELL

I. THE SENSE OF TASTE

THE special organ of taste is the taste bud, of which there are many hundreds, perhaps thousands, located on the surface of the tongue, and perhaps sparingly on the palate and sides of the pharynx. If you examine the surface of the tongue in the looking-glass, you will notice little red dots all over it. These dots are little funguslike papillæ. If you can see the tongue very far back, you may see several very much larger papillæ. All around the sides of the large papillæ at the base of the tongue and the small funguslike papillæ, there are little spherical bodies, composed of many spindle-shaped cells, between which lie the fine hairlike endings of the nerves of taste.

When a fluid substance, or a solid substance dissolved in the fluid, or one which may be dissolved by the saliva, is taken into the mouth, it comes into contact with these

minute taste buds, passes in between the spindle-shaped cells which form the taste buds, and stimulates the endings of the nerves of taste. This nerve sends the message to the brain, and one becomes conscious of the taste of the substance. Many of the sensations which we call taste are quite as much smell as taste; the flavor of coffee and of roast meat is a sensation largely due to the sense of smell rather than to that of taste. Sensations which are combinations of taste and smell should be called *flavors*.

There are only four different kinds of taste, — *salt, sour, bitter, sweet*. Most of the sensations which come to us while we are chewing our food, and especially most of the agreeable sensations, are really flavors, and not taste at all. When one has a cold in the head, and both nostrils are completely stopped up, so that he can breathe only through the mouth, the food tastes flat and flavorless. This is sufficient proof that the flavors depend upon a combined sensation of taste and smell.

Not all parts of the tongue are equally sensitive to these different tastes. The back part of the tongue, in the neighborhood of the large papillæ, is especially sensitive to bitter; the sides of the tongue are especially sensitive to acid; the middle of the tongue is especially sensitive to salt; and the tip of the tongue, to sweet.

II. THE SENSE OF SMELL

The specialized organ for smell is the upper part of the nose. The lower part, from the nostrils directly backward, is one of the air passages and part of the respiratory system, but all the upper part of the nose out of the direct line of breathing is devoted exclusively to the sense of smell, and there are nerve cells in the nose which stand

in the mucous membrane among the cells which pave the membrane.

Odorous substances, in the form of gas or of minute particles, may pass in with the inspired air or may pass up from the pharynx with the expired air, as is the case when one is chewing food. These odorous substances become dissolved in the moisture which covers the membrane in the upper passages of the nose. They then come in contact with the nerve cells of smell in the membrane, and these nerve cells send a message to the brain, and one becomes conscious of the smell; *i.e.* he receives the sensation of the smell.

The different kinds of taste we found to be limited to four, but the different kinds of smell are innumerable.

Nature provides animals with these senses for a purpose. It seems to be Nature's plan that animals should use these senses in the choice of their foods. In the case of beasts of prey, the sense of smell may be used in tracing their prey. These senses guide herbivorous animals in the choice of herbage. *A poisonous weed is rarely mistaken by them for a wholesome one.*

Man can be guided by his sense of smell as to the wholesomeness of the air which he is breathing, and his taste will serve in part as a guide to the choice of food.

An odor is remembered longer than any other sensation. This sensation calls up more quickly and forcibly some past experience than does any other sense impression.

To smell things simply because they produce a pleasing sensation, and to taste and eat or drink things simply because the taste or flavor is a pleasing sensation, is a perversion of Nature's laws which may be observed in man only, of all animals.

2. HEARING

THE ear is the special organ of the sense of hearing. That part of the ear which we can see on the outside of the head is only a sort of funnel for catching the sound and conducting it into the part of the ear where the sound is heard. The outer ear, together with the passage to the ear drum, is called the *external ear*. The *middle ear*, or *eardrum*, is a little cavity in the solid bone of the side of the head. Still deeper in the bone is the *internal ear*,

composed of a *vestibule*, from which open a coiled chamber similar to a snail shell, called the *cochlea*, and three *semicircular canals*.

The middle ear is called the *tympanum*, or *eardrum*, because of its resemblance to a drum. As you know, a drum has at least one drum-head, which is a vibrating membrane. Every drum is provided with a side opening. If this

side opening were not provided, the membrane would not vibrate freely, and the drum would have a dead, muffled sound. The side opening into the tympanum is provided by the *Eustachian tube*, a small canal which passes from the pharynx up to the middle ear.

These parts which have been described are shown in Figure 52. Study carefully this figure. Notice that the

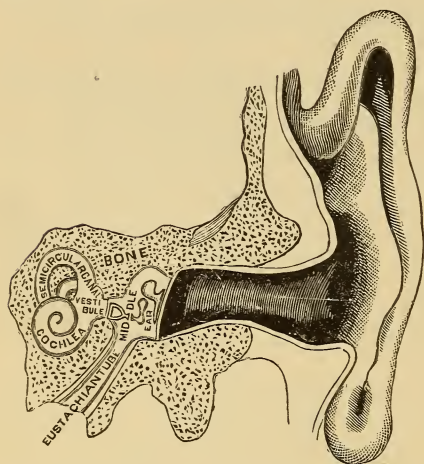


FIG. 52.—Section of the ear, showing the relative positions of the external, middle, and internal ear. [Tracy.]

middle ear, or tympanum, is divided from the canal which passes in from the external ear by the *drum membrane*, and that it is divided from the vestibule by a little membrane across what is called the *oval window*. Between the drum membrane and the oval window is a chain of *three bones*. The one which is attached to the drum membrane is called the *hammer*, the one which is attached to the membrane of the oval window is called the *stirrup*, and the one between, fastened to the hammer at one end and to the stirrup at the other, is called the *anvil*.

When the sound which passes in through the canal of the external ear makes the drum membrane vibrate back and forth, the hammer vibrates with it, and passes the vibration on through the anvil and stirrup to the membrane of the oval window. So the sound vibrations received by the ear are thus carried direct to the membrane of the oval window. The vestibule, cochlea, and canals of the internal ear are filled with liquid; the vibrations of the membrane of the oval window set the liquid into vibration.

There is stretched across the cochlea, from its center to its circumference, a membrane composed of thousands of little fibers lying side by side, some long and some short, those at the upper end being about twelve times as long as those at the lower end, reminding one of a harp with its long and short strings. The vibrations of the liquid set these fibers to vibrating. Upon the fibers stand cells, about which are the fibers of the auditory or hearing nerve. The vibrations of the fibers stimulate the nerves, and we become conscious of the sound.

The sense of hearing is one of the most useful to man and to other animals, because it may warn man of approaching dangers when they are still at a considerable

distance. It enables him to hear at a great distance a call for help or a shout of warning. It enables him through conversation to communicate his ideas to others. Through the ears we are made conscious of the joys and sorrows of our comrades; we hear their laughter as well as their sobs.

It is a part of Nature's plan for the sense of hearing to be cultivated and gratified for simple pleasure. It may be observed even in the habits of the lower animals. The summer night concert of the frogs and crickets, and the summer morning concert of birds, are sufficient evidence that the voice and the hearing are to be cultivated together for the entertainment and the pleasure of one's self and others. Music is elevating and enriching in its influence.

The most important thing to remember in the care of the ears is that no hard or irritating substance or instrument should be put into the canal of the ear, because there is danger of injuring the delicate drum membrane. If wax collects in the ear canal it may be gently removed with the little finger, covered with a handkerchief or wash-cloth. If the wax hardens in the ear, which frequently happens, causing some pain, it may be softened with one or two drops of sweet oil, or of fluid cosmoline, after which it can be easily removed with an ear spoon.

3. THE SENSE OF SEEING

THE eye is the special organ of this special sense. The eye is one of the most complex organs of the body, and the sense of sight is the most important of the special senses. Figure 53 shows what you could see in a comrade's eye if you were to look at it very carefully,

using, perhaps, a reading glass to magnify the parts somewhat. The eyeball is movable under the lids, and has a dense coat which shows in the corners of the eyes, but directly in front you see the black pupil of the eye, surrounded by the colored disk, brown in some eyes and blue or gray in others.

The eyeball is so delicate in its construction that it must be very thoroughly protected from dust and all other injurious things. These

protective parts, including the lashes, the brow, and tear apparatus, are called the appendages of the eye. The eyelids are the most important protection of the eye, keeping its transparent central portion moist and free from dust. Notice that the margins of the lids are supplied with long, stiff hairs. These are the eyelashes, and they assist in protecting the eye from dust. On the edges of the lids, notice the little dots. These mark the openings of minute oil glands within the lids. These oil the edges of the lid, to keep the tears from overflowing.

Above the outer corner of the eye and under the brow is a gland about as large as the last joint on your little finger. This is the tear gland, and its secretion, mostly water, with a little salt and mucus in it, pours through the little ducts under the upper lid. When one winks the eye, the upper lid spreads the tears over the surface,

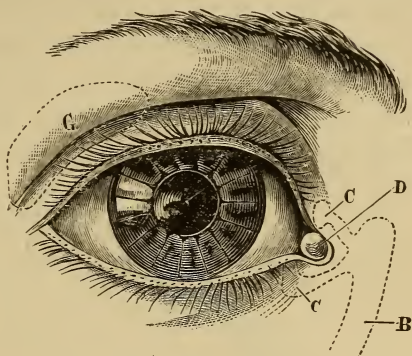


FIG. 53.—The eyelashes and the tear glands: *G*, tear gland; *D*, island around which the tears collect; *C*, tear canals; *S*, tear sac; *B*, nasal duct through which the tears drain off into the nose.

thus washing off the dust and making the surface fresh and bright. The tears are constantly evaporating from the surface of the eyeball, but there are always some left over, and these gradually collect down at the inner corner of the eye around a little island, which is marked *D* in the picture. On either side of this little island are two minute pores, leading into the tear canals, marked *C* in the picture. The two canals come together in what is called the tear sac, from which a large duct, called the nasal duct (*B*), conducts the tears into the nasal passage. If the tears flow rapidly, as when one is crying, they may come too fast to flow off through the little canals, and so may overflow upon the face; in that case they will also flow freely from the nose.

Among the appendages of the eye are the muscles which move the eye. These are six in number. One muscle turns the eye inward toward the nose, while the one opposite to it turns it outward. Then there are muscles which turn it upward or downward or obliquely. Sometimes one of these muscles is permanently contracted, thus keeping the eye turned in; then we say the person is cross-eyed, or has a squint. A specialist is usually able, by a simple operation, to loosen the muscles enough to straighten the eye.

The eyeball is nearly spherical, and has a dense outer coat called the sclerotic coat. The front part of this coat is curved outward and transparent, reminding one of a watch crystal. This is called the cornea, and through this the rays of light pass into the eye (Fig. 54). Just within the sclerotic coat is the choroid, which is a loose-meshed tissue, full of blood vessels and nerves. This coat contains an important muscular body called the ciliary muscle, and it is this coat which makes the

little colored curtain called the iris. This little curtain, the iris, is like the diaphragm of a camera, and through it there is a circular opening called the pupil. The muscles which it contains may dilate or contract the pupil according to the amount of light, or according to whether the object looked at is near or far away, — contracting to see near objects and dilating to see distant objects. The

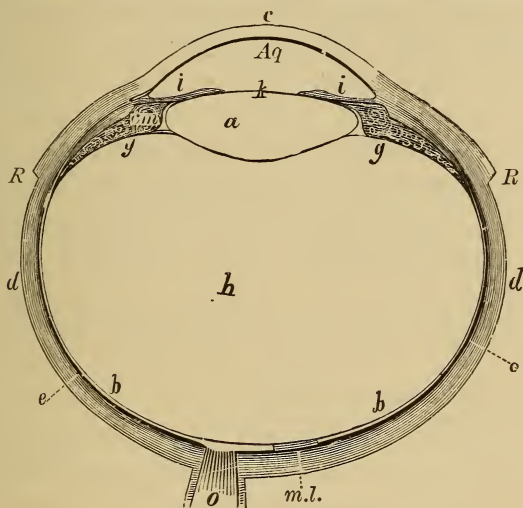


FIG. 54. — Horizontal section of the eyeball: *d*, sclerotic coat; *c*, cornea; *e*, choroid coat; *i*, iris; *Aq*, aqueous humor; *a*, crystalline lens; *h*, vitreous humor; *b*, retina; *O*, optic nerve; *cm*, ciliary muscle; *R*, place where muscles were attached.

light which enters the eye through the cornea, passing through the pupil of the eye, must be focused upon the sensitive portion of the eye, the retina. The focusing is done by the crystalline lens. The crystalline lens is held in place by little ligaments, which pass out from the ciliary muscle. The contraction of this muscle will cause the lens to become more convex, thus focusing the light from near objects upon the retina.

The retina is composed of two coats, the outer coat consisting of a sepia-black pigment which absorbs the light, while the inner coat (shown white in the figure) consists of the nerve cells of sight. The eye nerve or optic nerve passes from the base of the brain direct to the ball of the eye, and enters it at *O*, Figure 54, the fibers spreading out to pass to the nerve cells of the retina. The most sensitive part of the retina is just at the outside of the optic nerve, and is marked *m.l.* in the figure. That part of the eyeball in front of the crystalline lens, and back of the cornea, is filled with a limpid, transparent fluid called the *aqueous humor*, while that part back of the crystalline lens and comprising most of the ball is filled with a viscid liquid of much greater consistency than the aqueous humor, which is called the *vitreous humor*.

These general rules may be given for the care of the eyes : —

- I. Never read by a dim light.
- II. Never read by a flickering or rapidly changing light.
- III. Never read in too bright a light, for example, when the sun is shining full upon the page.
- IV. Let the light shine upon the page and not upon the eyes. The light should fall upon the page from the side or from behind.

When the eye is at rest, distant objects are focused upon the retina ; to see near objects it is necessary for the muscle which controls the lens to contract ; to look constantly at near objects requires a constant contraction of this muscle. We know how hard it is to keep a muscle contracted for a long time, and we can see that it would strain the eyes to look for a long time continuously at a close object, so we can appreciate the next rule.

V. When reading a book or studying any close object, either close the eyes or look off at a distant object every few minutes to rest the eyes. If one has used the eyes too long and has tired them, bathing them in cold water is to be advised. If one cannot see clearly distant objects, or if one has headaches that cannot be definitely traced to some other cause, he should consult a physician to see if the eyes need the assistance of glasses. The free use of either alcohol or tobacco may cause a very serious injury to the sight.

During the last few years railroad managers have observed the injurious effect of alcohol upon their workmen when occupying positions that require delicacy of touch, keenness of vision, and acuteness of hearing. Not long since a large railroad corporation investigated the conditions surrounding every accident that had occurred on its lines during the preceding five years. It was found that forty per cent of all accidents were due entirely or in part to drinking men. In eighteen per cent it was strongly suspected that the drinking habits of employees was the cause of the accidents. The company in a single year lost property to the amount of one million dollars through the incompetency of beer-drinking engineers and switchmen.

Michigan has passed a law which imposes a heavy penalty upon those railroad companies which employ men who are in the habit of using alcoholic intoxicants. Railroad managers, as practical business men, are recognizing the utility of employing total abstainers as a measure calculated to reduce financial losses on account of accidents.

Some railroad companies prohibit their employees from drinking any kind of intoxicants or entering a drinking saloon during working hours, while other railroad companies demand from their employees the signing of a total abstinence pledge which shall hold good for every hour of every day.

This action of railroad managers shows their appreciation of the doctrine that even small quantities of alcohol impair the organs of special sense, and that in order to do the best work in railroad business the workmen must have eyes, ears, and hands perfectly free from the poisonous influence of alcohol. — J. W. GROSVENOR, M.D., *Journal of American Medical Association*, June, 1896, p. 126.

REVIEW OF THE SPECIAL SENSES

1. How many different kinds of taste are there? Name several pleasing flavors. What is the special organ of the sense of taste?
2. What is the special organ of the sense of smell? Name several odors or perfumes which are pleasing.
3. What seems to be Nature's plan for the use of the senses of smell and taste?
4. Describe the special organ of hearing; its three divisions and the way each division is made and the work it does.
5. What reason have we for believing that it is in harmony with Nature's plan that we cultivate the taste for music?
6. How should the ear be cared for?
7. Draw a picture of the eye, showing all of the principal structures. Describe the drawing, and tell what is the work of each one of the structures.
8. Give the five rules for the care of the eyes.
9. Why cannot railroad engineers do their work so well if they have been indulging in moderate drinks of alcoholic beverages?

CHAPTER XII.—THE NERVOUS SYSTEM— THE BRAIN, THE SPINAL CORD, AND THE NERVES

THE subject of this chapter is not a new one. The reader will remember that in Chapter III of General Physiology, under the heading, "How the Different Organs are made to work in Harmony," the nervous system was studied at considerable length. This chapter will not be a repetition of what was given there, but an extension of it. In order to understand what is to follow in this chapter it will be necessary to review again carefully the chapter just referred to. To that end you may look up again the answers to the following questions.

I. In what respects is the animal body similar to a large colony?

II. How are the different individuals of a colony made to work in harmony?

III. How is a railroad company able to send over its lines a large number of trains without having numerous collisions?

IV. Why is it necessary that the work of the stomach be done at any particular time? Why cannot the stomach secrete its juice at any time?

V. What would happen if the change of rate of the heart beat or if the change of rate and depth of respiration should take place at any time without reference to what the muscles were doing?

VI. What two things are necessary in bringing harmony

of action among those who work for a great railroad company? (For example, see beginning of Lesson 2, Chapter III.)

VII. What is a *nerve trunk*? a *nerve fiber*? a *nerve cell*?

VIII. What is the *sympathetic nervous system*?

IX. How does the sympathetic system perform its work?

X. What is the relation between the sympathetic system and the *spinal cord*?

XI. How is a message sent from the brain to the muscles of the arm? (See Lesson 3, Chapter III.)

XII. What is *voluntary action*?

XIII. In how many directions must messages be sent when one sees something which he desires, and reaches for it?

XIV. What is *reflex action*?

XV. Does the brain receive any sensation in the case of a reflex action? If so, when is this sensation received, before or after the act occurs?

XVI. What is the relation between voluntary action and *automatic motion*?

XVII. What is *habit*, and what is its relation to automatic action?

1. THE STRUCTURE AND FUNCTION OF THE BRAIN

I. NERVE CELLS

NERVE cells are the most remarkable cells in the animal body, for their variety in shape, as well as for their size. Figure 55 shows a typical nerve cell. This cell came from the spinal cord. Some of the cell bodies in the spinal cord are so large that they may be seen with the unaided eye, and have branches reaching from the cord to the hand or foot.

Notice in this cell in Figure 55 how irregular the outline of the cell body is. Each little projection of the cell body passes out into a treelike branch, and because of their resemblance to a tree they are called *dendrites*.

The *nerve cell*, like other cells, is composed of protoplasm. These cells have very large *nuclei*, and one or more *nucleoli*. The protoplasm of the nerve cells is granular. There is usually a collection of *pigment* (Fig. 55, *P*) in each cell. The *dendrites* are protoplasmic branches of the cell. The dendrites bring messages to the cell. Through the dendrites the cell body may be in communication with numerous other cells. Though a cell receives messages from various sources, it can send a message in only one direction. One of the extensions of the cell is called a *neurite*. It is the neurite which carries the message away, and under no circumstances can the neurite bring messages to the cell. Some nerve cells have a long dendrite which may bring a message from a long distance ; those nerve cells also have a neurite. The sensory nerves, which carry messages from the skin to the brain, are long dendrites ; the cell body is located near the spinal cord, and the neurite passes into the cord.

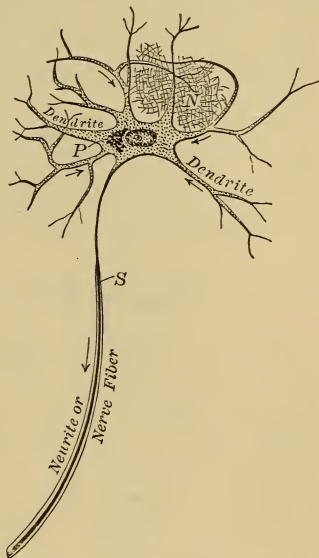


FIG. 55. — A nerve cell from the anterior horn of the spinal cord. The *Dendrites* carry messages to the nerve cell and the *Neurite* carries messages away from the nerve cell. *Neuroglia* (*N*) is the supporting tissue. *Insulating material* (*S*), pigment (*P*).

II. NERVE SUBSTANCE

The substance of the central nervous system, that is, the spinal cord and brain, comprises two tissues, *nerve tissue* and *supporting tissue*. The supporting tissue is a very fine-meshed connective tissue called *neuroglia* (see Fig. 55, *N*). Only a small amount is shown in that figure, in order not to obscure the details of the nerve cell, but the neuroglia tissue fills all the space between the cells and nerves, serving really as a packing to hold the cells in place, as we use excelsior for packing. It is the nerve tissue, made up of nerve cells, which does the work of the system.

III. NERVE CENTERS AND NERVE TRUNKS

The cell bodies are not scattered promiscuously through the nervous system, but are gathered into groups. This seems to afford easier communication from one cell to another through their short-branched dendrites. Such a group of cells is called a *nerve center*, and in its action on the nervous system is similar to the central office of a telephone system. To such a center there are fibers coming from a distance bringing messages, and from the center the message may be forwarded to one of the distant parts of the system.

The nerve fibers which pass from the cell bodies or from nerve centers are insulated one from another through the means of a white substance which makes a sheath about each fiber. A bundle of these fibers is called a nerve tract while it is still within the spinal cord or brain, but when it emerges from these organs and passes out as a rounded nerve cord, we call it a nerve trunk. Because of the insulating material which surrounds the fibers, nerve trunks and nerve tracts are white in color, and because

of the protoplasm of which nerve cells are made, the nerve centers have a grayish color. This led the anatomists and physiologists in times past to classify nerve substance as gray matter and white matter.

2. THE SPINAL CORD AND BRAIN

I. THE SPINAL CORD

FIGURE 56 gives a view of the whole central nervous system, with the spinal cord as seen from behind. The nervous system may be said to comprise two organs: first, the brain; second, the spinal cord. The spinal cord represents a series of important nerve centers, around which are grouped bundles of nerve tracts (Fig. 57). The grayish outline of the centers makes a figure something like the letter H when the cord is cut across; and all the substance outside of the H represents tracts or bundles of fibers which are passing upward toward

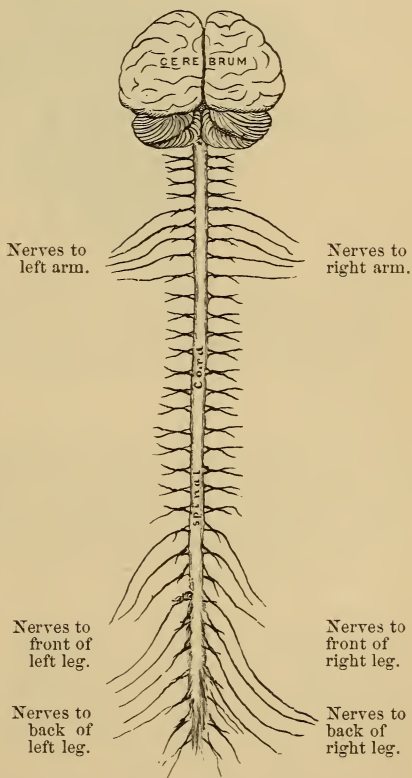


FIG. 56. — Brain and spinal cord, with the thirty-one pairs of spinal nerves.

the brain or downward from the brain. They are simply cut-off fibers in this picture (Fig. 57).

The centers for motion in this spinal cord are in the front horns of the H. Reflex action has been described in Chapter III. If we make a careful study of Figure 57, we can see how this reflex action is brought about. Suppose something irritates the skin. A message is carried along the long dendrite reaching from the skin to the

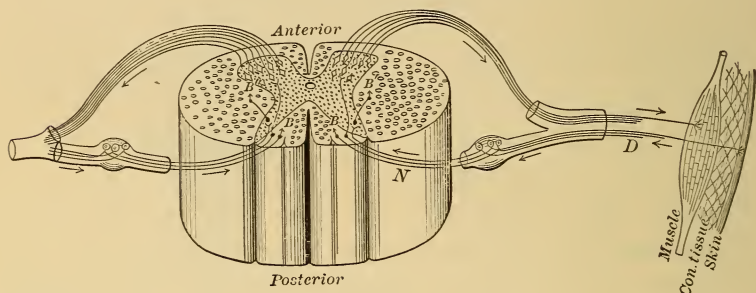


FIG. 57. — A diagram of a slice of the spinal cord as seen from behind, to show how the sensation is conveyed to the ganglia of the posterior root through the long dendrite *D*, thence to the cord through the neurite *N*. Arrived in the cord it may go to the brain as at *B'* or *B''*. But instead of passing to the brain it may pass to the cells of the anterior gray horn, and cause a reflex act.

nerve cell (the ganglion on the posterior root), and from this cell body a message is forwarded along the neurite into the posterior gray horn of the spinal cord, whence it is communicated to the brain, as well as to the center of motion in the anterior gray horn. Without waiting for a reply from the brain, the cells of motion in the anterior gray horn may send a message to the muscle through the anterior root along the motor nerve, as shown in the figure, and the muscle may contract, drawing the skin away from the irritating object before even the brain knows what is taking place.

II. THE BRAIN

Figure 56 shows the posterior view of the brain, composed of the great cerebrum, subdivided by the fissure into two hemispheres, below which is the much smaller cerebellum. Figure 58 shows more clearly the relative sizes of the cerebrum and cerebellum, and shows the brain from a side



FIG. 58. — Side view of brain, showing the large cerebrum with its surface in folds and fissures, the small cerebellum below the back part of the cerebrum, and the medulla passing downward from the base of the brain. The word "Leg" shows where the brain is at work when it sends messages to the leg; similarly for head, arm, face, and for the organs of speech. "Hearing" and "Vision" show where the brain receives the sensations of hearing and sight.

view. The surface of the brain is thrown into a series of very irregular folds, called convolutions. The purpose of these convolutions seems to be to increase the surface of the brain. It is upon the surface of the brain that the cells composing the nerve centers are located, while the internal portion of the brain is made

up largely of white fibers connecting different brain centers. By increasing the surface of the brain, the possible number of cell bodies is increased, thus increasing the brain activity. Highly civilized and educated races of men have brains which have more and deeper convolutions than do the half-civilized and ignorant savages. The savages, on the other hand, have more convolutions in their brains than does the monkey or the dog, and these, in turn, more than animals which stand still lower in the scale.

The brain, then, represents a number of nerve centers grouped into a compact mass. Different brain centers preside over different functions of the body (Fig. 58, Leg, Arm, etc.). As there are nerve trunks passing from the spinal cord out to muscles and organs of sense, so from the brain there are nerve trunks passing out to muscles and nerve endings. Twelve pairs of these nerves extend from the brain and from the medulla to various structures of the head, face, throat, and thorax.

The cerebrum contains the centers which preside over, or which are the seat of, consciousness of sensations, such as of sight, sounds, odors, and feelings, as well as the centers of various emotions, such as fear, anger, love, hate. It is the seat of all thought, of reason, and of the will power.

The cerebellum is the center which presides over the movements of the body and limbs, making these movements smooth and graceful. It helps to keep the body balanced in walking, standing, or riding.

In the medulla oblongata, shown in Figure 58, there are numerous centers which preside over the movements of the heart, the respiratory organs, and the various organs of the digestive tract; and which also preside over the con-

strictors and dilators of the arteries, changing the amount of blood which is to flow to a particular organ at a particular time.

III. EDUCATION OF CORD AND BRAIN

As the muscles can be developed by systematic exercise, so the nervous system may be cultivated and educated. Any particular act may be very hard to perform at first, and may require the whole attention to perform it even clumsily when it is first done, but, if often repeated, it may finally be done with perfect grace and precision, while one is thinking of something else. It thus becomes an automatic action. Methods of thought, and certain lines of thought, may become habitual in a measure, just as combinations of motions may become habitual and automatic. This makes it a matter of very great importance for all young people to cultivate correct habits of action and of thought.

3. THE HYGIENE OF THE NERVOUS SYSTEM

I. EXERCISE AND REST

LIKE all other tissues of the body, nerve tissue requires a certain amount of exercise and a certain amount of rest, if it is to be vigorous and healthy. As all of the knowledge which we possess comes to us through sensation, it is very important that the acuteness of sensation be cultivated. This can be done only by close attention to things which one is observing. One should train himself to give his undivided attention to anything which he is observing with his senses. If he is studying the color and texture of an object through his senses of sight and touch, he

should give his undivided attention to the study. If he is listening to a lecture or a concert, he should give his undivided attention to that, thus not only cultivating a habit of concentration, but also cultivating the acuteness of the senses. At least one or two hours of intense mental activity is required each day, if the mind of a young person is to develop a power of close application and correct, logical thinking.

But tissues that work hard must also rest perfectly. Perfect rest of the brain can be gotten only during sleep. Every person should have from seven to eight hours of sound sleep out of every twenty-four if he is to continue in vigorous health throughout his allotted years.

II. THE INFLUENCE OF ALCOHOL

“ALCOHOL acts primarily on the nerve cells, changing their granular matter, breaking up their nutrition, and changing their dynamic force. This action is followed by contraction of the dendrites, swelling and atrophy of these fibers, also shrinking of cell walls, as in fatigue, and coalescing and disappearance of the granular matter of protoplasm.”¹

“Alcohol does not affect all the spinal cells equally, and in the early stages the changes are rather indefinite, a greater sharpness of contour being the most obvious. In the cerebrum the cells appear as mere shadows, both substances disappearing, whilst the nuclei are also altered.”²

“Just why the alcohol should select a set of nerves on which to act at one time and a different set at another does not at once appear, but it is a well-authenticated fact

¹ *Journal of the American Medical Association*, November, 1898.

² London *Lancet*, October 31, 1896, p. 1245.

that it has a selective power. Most likely the explanation lies in the chemical or electrical condition of the white substance at the time of action, or it may be attributable to the different chemical constituents of the liquor used.”¹

“Professor Kraepelin of Heidelberg tried a number of experiments on individuals, with the object of seeing whether a small quantity of alcohol hindered the nervous transmission of intelligence to the brain. Flags were raised at a given distance, and the exact time was noted when the various men experimented upon observed the raising of the flag. The result proved that the watchers who had been given a small quantity of alcohol, though they felt that they had seen the flag rise sooner than those who had received no alcohol, actually took longer.”

Professor Woodhead says, “After careful examination of the whole question, physiologists—and among physiologists I include those who maintain alcohol may be useful, as well as those who hold that it is harmful—have come to the conclusion that the principal action of alcohol is to blunt sensation, and to remove what we may call the power of inhibition by blunting the higher centers of the brain.”

Professor David Starr Jordan in the *Popular Science Monthly*, February, 1898, said: “The healthy mind stands in clear and normal relations with Nature. It feels pain as pain. It feels action as pleasure. The drug which conceals pain or gives false pleasure when pleasure does not exist forces a lie upon the nervous system. The drug which disposes to reverie rather than to work, which makes us feel well when we are not well, destroys the sanity of life. All stimulants, narcotics, tonics, which affect the nervous system in whatever way, reduce the truthfulness

¹ Dr. Wilkins, in the *New York Medical Journal*, September 22, 1894.

ness of sensation, thought, and action. Toward insanity all such influences lead; and their effect, slight though it be, is of the same nature as mania. The man who would see clearly, think truthfully, and act effectively must avoid them all. Emergency aside, he cannot safely force upon his nervous system even the smallest falsehood."

Dr. Hammond said: "The more purely intellectual qualities of the mind rarely escape being involved in the general disturbance [caused by alcohol]. The power of application, of appreciating the bearing of facts, of drawing distinctions, of exercising the judgment aright, and even of comprehension, are all more or less impaired. The memory is among the first faculties to suffer. . . . The will is always lessened in force and activity. The ability to determine between two or more alternatives, to resolve to act when action is necessary, no longer exists in full power, and the individual becomes vacillating, uncertain, the prey to his various passions, and to the influence of vicious counsels."

"Helmholtz told us in his autobiography that if he took wine while occupied with a mathematical or scientific problem, his thinking powers were interfered with, and he had to wait for the alcoholic effects to work off before his inspiration returned." ¹

"Finally we have still to declare that alcohol hinders the action of the highest mental faculties. A remark made by Helmholtz at the celebration of his seventieth birthday is very interesting in this connection. He spoke of the ideas flashing up from the depths of the unknown soul, that lies at the foundation of every truly creative intellectual production, and closed his account of their

¹ Dr. Adolph Rupp, *New York Medical Journal*, July 9, 1898.

origin with these words: 'The smallest quantity of an alcoholic beverage seemed to frighten these ideas away.'"¹

W. Boyd Dawkins says: "I cannot drink beer when I am using my brain, and do not take it when I have anything to think about."²

"Some people imagine that after the use of alcohol they can do things more quickly, that they are brisker and sharper, but exact measurement shows that they are slower and less accurate. Men believe that they are wiser and brighter, but their sayings are more automatic and apt to be profane. To quote Dr. Lauder Brunton, of Oxford University, England, '*It produces progressive paralysis of the judgment,*' and this begins with the first glass. Men say and do, even after a single glass of drink, what they would not say or do without it, and therefore it clearly affects the brain and diminishes self-control."³

Professor von Bunge,⁴ of Switzerland, says that, "The stimulating action which alcohol appears to exert on the brain functions is only a paralytic action. The cerebral functions which are first interfered with are *the power of clear judgment and reason*. No man ever became witty by aid of spirituous drinks. The lively gesticulations and useless exertions of intoxicated people are due to paralysis, — the restraining influences, which prevent a sober man from uselessly expending his strength, being removed.'

"The capital argument against alcohol, that which must eventually condemn its use, is this, that *it takes away all*

¹ Adolph Fick, Professor of Physiology, Wurzburg, Germany.

² Quoted by Dr. M. L. Holbrook, *Journal Medical Temperance Association*, January, 1898, p. 21.

³ Dr. G. Sims Woodhead, Professor of Pathology, Cambridge University, England.

⁴ G. von Bunge, Professor of Physiological Chemistry, University of Basel, in *Text-book of Physiological and Pathological Chemistry*.

*the reserved control, the power of mastership, and therefore offends against the splendid pride in himself or herself, which is fundamental in every man or woman worth anything."*¹

III. THE EFFECTS OF TOBACCO UPON BRAIN WORK

"I have been a teacher in Connecticut twenty years. . . . In boys addicted to this (tobacco) habit I find a nervous irritability, and inability to do the work that properly belongs to boys of their age. Where the habit has been abandoned, I have found a marked improvement, both mentally and physically."²

REVIEW OF THE NERVOUS SYSTEM

1. Before going on with this review be sure that you can answer the seventeen questions at the beginning of this chapter.

2. Draw a figure of a nerve cell; draw and describe the dendrites. What is the neurite?

3. How many kinds of tissue are there in the nervous system?

4. What are nerve centers?

5. Why was nervous tissue formerly classified as "white and gray matter"?

6. Draw a figure representing a section of the spinal cord.

7. Of how many main divisions is the brain composed?

8. Of what importance are the convolutions of the brain? What is the principal work of the Cerebrum? Of the Cerebellum? Of the Medulla Oblongata?

9. How may the brain be improved? Why does the brain need rest?

10. What is the effect of alcohol upon the brain?

11. What is the effect of tobacco upon the brains of young and growing persons?

¹ Dr. John Johnson, quoting Walt Whitman.

² Maria F. Starr, Principal High Street School, New London, Conn.

CHAPTER XIII. — THE MUSCLES — HOW THE BODY MOVES

1. THE MUSCLES: HOW THEY ARE MADE, HOW THEY ARE ARRANGED, AND HOW THEY WORK

FIGURE 59 shows how the body would look if the skin, and the layer of connective tissue and fat beneath the skin, were all removed, leaving the muscles bare and open to view. Though a great number of muscles are shown in the figure, those shown are only a small proportion of all the muscles in the body ; the figure shows only the outside muscles.

There are about five hundred voluntary muscles. The voluntary muscles are those that are under the control of the will ; the muscles of the legs, arms, body, neck, and face are all voluntary muscles. These voluntary muscles are, most of them, much larger than the involuntary, such as those in the walls of the stomach and intestines, and usually contract with a quicker and stronger action than do the involuntary muscles.

By studying the limbs in the figure, especially the arm at the right, you will notice that the upper or middle portions of these muscles are large and full, and that from the largest part of the muscle it tapers down to a small cord at the wrist or ankle. This small cord at the end of the muscle is not composed of muscular tissue, but of very dense and inelastic connective tissue. If the full, round muscle extended down over the wrists and

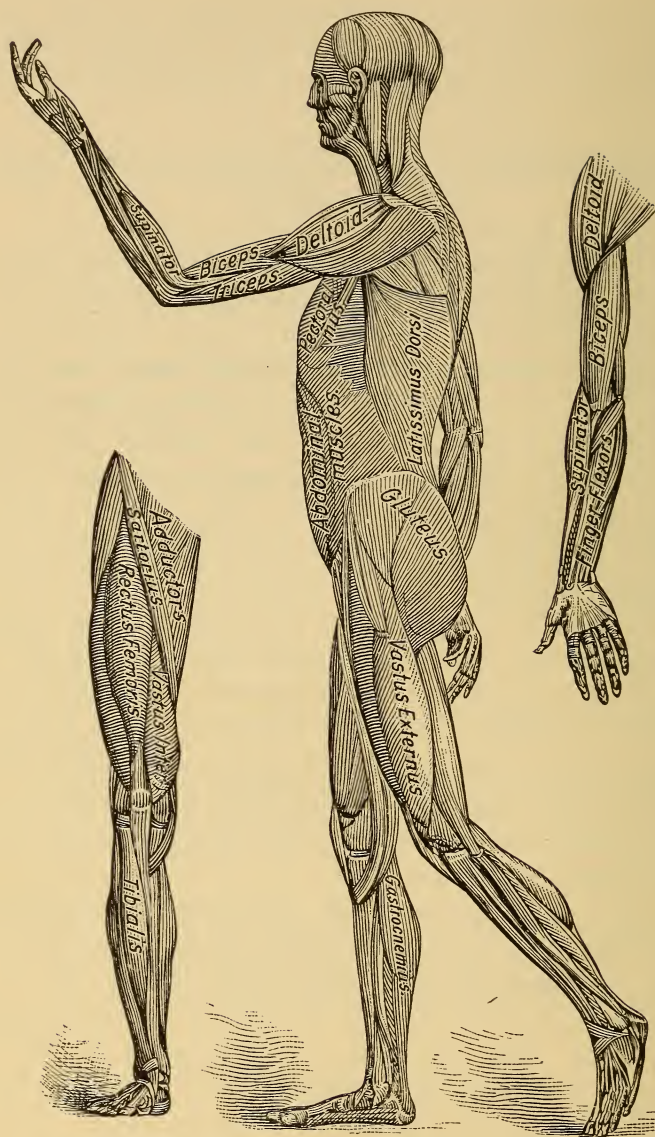


FIG. 59. — The muscular system. [Tracy.]

ankles, it would make these as large around as the forearm or calf, and that would make the wrist and ankle very clumsy and awkward.

These glistening white cords spread out into a fan shape at the end where the muscle attaches to it. This glistening white cord passes over the wrist or ankle, down to the hand or foot, where it is attached to the bone, and through this tendon the muscle can move the hands and feet, with their fingers and toes. Muscles are generally attached to the bones at each end, and use the bones as aids to accomplish their work. The bones serve as levers.

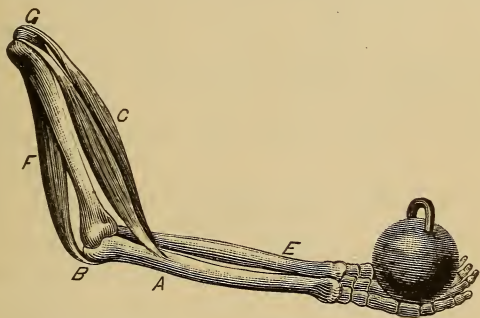


FIG. 60. — The arrangement of bones and muscles by which the arm is bent: *A*, the radius; *B*, the elbow; *C*, biceps; *E*, ulna; *F*, triceps; *G*, shoulder joint.

Figure 60 shows the bones of the arm, together with the two most important muscles. In the position in which the arm is shown, the biceps muscle supports the weight which is resting in the hand. The bones of the forearm, that is, the radius and ulna, act as a lever. This lever is fastened at the elbow joint, that is, the elbow is the fulcrum of the lever. The biceps muscle represents the power which pulls upon the lever between the fulcrum and the weight resting in the hand. When the fulcrum,

the power, and the weight are arranged in this way, the lever is said to be one of the third order. It is easy to see that a slight contraction of the biceps muscle will move the weight a greater distance than the actual contraction of the muscle. In all levers of the third order, the weight moves through a greater distance than the power, that is, there is a gain in the distance moved by the weight, but a loss in power.

Figure 61 shows the three orders of levers. In the lever of the first order, notice that the fulcrum is between the power and the weight. In the lever of the second

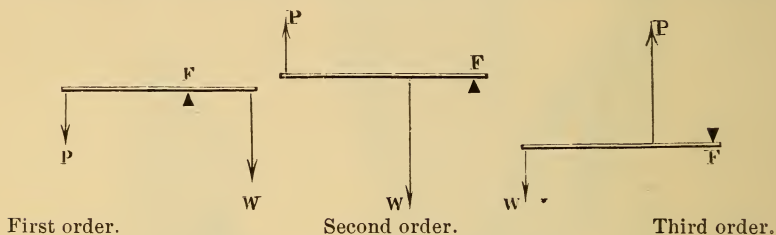


FIG. 61. — The three orders of levers.

order, the weight is between the fulcrum and the power, while in the third order, the power is between the fulcrum and the weight. In the lever of the first order, the power will move through a greater distance than the weight, as long as the fulcrum is nearer to the weight than to the power, but when the fulcrum gets nearer to the power than to the weight, then the weight will move through a greater distance than the power. In a lever of the second order, the weight is always nearer to the fulcrum than the power is, and will, therefore, always be greater than the power, and will always move through a smaller distance than the power. In the third order, the power is always nearer to the fulcrum than the weight is, and will,

therefore, always be greater than the weight, and will move through a shorter distance than the weight.

EXPERIMENTS AND PROBLEMS

1. The leg of a chicken, including the toes and as much of the drumstick as possible, may be obtained from a butcher or from the kitchen. Remove the skin, and separate out the muscles and tendons. Notice the effect upon the movements of the toes when the different muscles or tendons are pulled.

2. Refer to Figure 61. What order of lever is the foot when one lifts his weight upon the toes by a contraction of the muscles on the back of the calf? What kind of lever does the foot make when one, without putting the heel upon the floor, lifts a weight which rests upon the toes?

3. What kind of a lever is the lower jaw during the process of chewing? What lever is the foot when one rests the weight of the body upon the heel?

4. What order of lever does one make of one's arm, if one takes a weight in the right hand and holds the right arm in such a way that the forearm will be horizontal and above the head; then, holding the upper arm still, straightens the arm, thus lifting the weight up? Perhaps this problem could be understood better if you should turn Figure 60 upside down.

2. THE HYGIENE OF THE MUSCLES

FROM what has been said in previous lessons, you know that the work of the muscles consists in generating the heat which keeps the body warm, and also in producing

the motions of the body. They produce these motions by shortening and thus pulling up their tendons, and moving the bones. The stronger the muscles, the more work they are able to perform, both in warming the body and in bodily movements.

The first thing required by the muscles is nourishing food, and plenty of it. No part of the body is so sensitive to changes in the food as is the muscular system.

I. EXERCISE AND REST

The muscles, like the brain and other organs, are developed by exercise. Nearly all young animals play. Play is Nature's method for exercising the muscles, brain, and senses. One should choose for exercise those movements which require quickness and accuracy, rather than those which require great strength. To most people, calisthenics and individual gymnastics are uninteresting. It has been shown by years of observation on the part of men who have made a life study of the development of the nerves and muscles, that the most wholesome exercise is that obtained in games of skill and agility in which several individuals are contesting. Engaged in such a game, one loses all thoughts of himself and of the object of his exercise in his endeavors to win points in the game. Among the best games for the all-around development of the body are tennis, basket ball, hand ball, baseball, cricket, football, la crosse, and golf.

One should not exercise severely within half an hour before a meal, or within half an hour after a light meal or one hour after a heavy meal. Fatigue or weariness is Nature's notice to take a rest. It has been stated in a previous lesson that when the brain and the muscles both

call at the same time upon the circulatory system for more blood, the muscles will get it, and the brain will go without. For this reason, one should do his studying first, and his playing or work afterward. Some have not a choice in the matter, and are obliged to study after their work, if they study at all; but if one has a choice of the order in which he will perform his tasks, he will be wise to do his brain work first, while the muscles are at perfect rest; then if he goes out in the latter part of the day and takes vigorous muscular exercise, or does his muscular work, he will withdraw the excess of blood from the brain, thus making it easier for the brain to rest at night in a dreamless, restful sleep.

II. THE EFFECT OF ALCOHOL ON THE MUSCLES

The use of alcoholic beverages decreases the muscular power, as is shown by the following incident, quoted from the *Weekly Telegraph*, London, 1897: An English contractor, while erecting a large bridge in Scotland, was surprised at the apparent muscular power of the Highlanders whom he engaged. Having contracted for excavating a canal in England, he engaged about twenty Highlanders to accompany him southward. Several disputes occurred between these northerners and the Englishmen with whom they worked upon the canal, and the Highlanders were made the butt of many a jeer relative to the simple bread and milk fare on which they were contented to exist, thus saving the greater part of their wages to bring back to their friends and families. To settle these disputes, a wager was made that twelve Highlanders could not excavate a certain number of yards in the same time as an equal number of the "better fed"

Englishmen. Everything being fixed, a table was laid out with meat and ale for the Englishmen, while the Scotch had, besides their bread and milk, no other preparation for refreshment except what a can of fresh water afforded. But the point in dispute was, after a fatiguing day's work, decided in favor of the Highlanders, and while the Englishmen were totally exhausted by their exercise, the Highlanders still had a good reserve of strength and, in their enthusiasm at their success, danced their national Strathspey in token of their victory.

Dr. DeVaucleroy, Professor of Hygiene in the Military School of Belgium, says: "The influence of alcohol upon muscular work has been established permanently. It has been demonstrated that man works better when he does not use these pretended stimulants. The physiological experiments of Destreé have established that alcohol is a paralyzer of muscular work. It excites at first, but this excitation is altogether transient, and is followed immediately by depression."

English and American athletes have long recognized the very great importance on the part of those who are to enter contests, of total abstinence during the period of training as well as during the period of contest. Nearly ten years ago this began to be recognized among the German university students, and one club after another abandoned the morning drinking bout in order to better fit themselves for athletic contests in which their members wished to take part.

Dr. Charles Stewart says that, "In a number of experiments carried out with the idea of ascertaining the effect of alcohol upon muscular force, it was found that in every case where alcohol was taken, muscular force was diminished, even when so small an amount as one half dram

(one half a teaspoonful) of alcohol was used. In these experiments it was found that nonabstainers were affected as well as abstainers. The deceptive nature of alcohol was manifested in every case, each individual feeling sure that he could accomplish more than he could before taking the alcohol.”¹

Many hundreds of similar experiments might be cited, but they *all demonstrate the same thing, namely, that the use of alcohol decreases the force and efficiency of the muscular system.*

ALCOHOL AS AN ARMY RATION

“The uselessness, if not the harmfulness, of even moderate doses of alcohol rests on better evidence than scientific deduction and experiments. In connection with the sanitation of armies, thousands of experiments upon large bodies of men have been made, and have led to the result that, in peace and war, in every climate, in heat, cold, and rain, soldiers are better able to endure the fatigues of the most exhausting marches when they are not allowed any alcohol. A similar result is observed in the case of the navies and on thousands of commercial vessels belonging to England and America, which put to sea without a drop of alcohol. Most whalers are manned by total abstainers.”²

In a paper entitled “War’s Aftermath,” in the *May Forum*, 1899, Mr. W. K. Rose, Reuter’s correspondent in the Soudan campaign, said: “Alcoholic drinks are, however, now eschewed by the best commanders. ‘Havelock’s saints’ performed their heroic feat in marching and fighting in the Indian mutiny on coffee alone as a beverage.

¹ *Journal of the Medical Temperance Association*, January, 1897, p. 54.

² Professor Bunge.

In the Red River expedition of 1870, under General Wolseley, no spirit ration was issued; and certainly, says the *Medical Report*, no men could have enjoyed better health than did the troops without it. Out of the seven hundred and ten men engaged only five were invalided. The old-fashioned rum ration was not issued in the Ashantee War of 1873, — which was also under the command of General Wolseley, — though a small amount was given to individuals when especially prescribed by the medical officers. The result was that, in the pestilential climate of the hinterland of the Gold Coast, the total mortality from all causes was only 3.14 per cent of the whole strength of the British troops. In the Kaffir War of 1877–1878 rum as a ration was strictly prohibited; and the good health of the troops was attributed to enforced abstinence from spirituous liquors.”

Colonel Geary, in a paper before the Sanitary Congress at Stafford, stated that during the Abyssinian campaign, for six weeks advancing upon and retiring from Magdala, there was no alcohol, no crime, and the percentage of sick was less than in any part of the British army at home or abroad, while the troops performed arduous marches on scanty food and often with bad water.

Lord Roberts, the commander in the Boer campaign, says that the effective strength of an army is always proportionately greater according to the number of total abstainers in the ranks.

“To-day it is a great feather in the headgear of the advocates of military total abstinence that Lord Kitchener’s recent victory was won for him by an army of teetotalers, who made phenomenal forced marches through the desert, under a burning sun, and in a climate famed for its power to kill or prematurely age the unacclimated.

Indeed, it is said that never has there been a British campaign occasioning so little sickness and profiting by so much endurance.”¹

ALCOHOL A CAUSE OF MENTAL DISORDERS

“If you look round and try to find out the primary causes of disease and poverty and crime and misery, you are over and over again thrown back on the use of alcohol. One cannot read the newspapers and reports of judges without seeing that alcohol accounts for a very large proportion of what is evil in our daily life. It is sapping the foundation of our national life, and if we could do away with all the disease and poverty and crime caused by alcohol, the questions which confront us would be solved very easily.”²

THE INFLUENCE OF ALCOHOL UPON THE MORALS

“The most highly specialized characteristics are first impaired, and thus the spiritual faculty, if I may so term it, first becomes blunted by the use of alcohol. Following this in rapid succession there is blunting of the moral sense ; a slight, though distinctly perceptible, interference with the intellectual faculties, which leads to what we might call blurring of the reasoning power ; then follows a distinct diminution in the power of rapidity and accuracy of perception. At none of these stages would a man admit that he was under the influence of alcohol ; but these powers are just as assuredly under its influence as are the muscles which can no longer act coördinately to enable a man to walk straight.”³

¹ *Washington Star*.

² Professor G. Simms Woodhead.

³ Professor Woodhead.

“The nervous system cannot escape injury from the ingestion of alcoholic drinks. It fails to receive correct impressions; it fails to send out correct orders; it fails to receive proper rest. . . . The continued use of alcohol causes the nervous centers to undergo degeneration, and the most serious diseases known to medical science ensue.”¹

¹ George H. McMichael, M.D., Buffalo, N.Y.

CHAPTER XIV.—THE SKELETON — THE FRAMEWORK OF THE BODY

THE earthworm has no framework; he cannot hold his body erect, all of his movements must be slow and groveling. The butterfly has a framework. Portions of this framework support the delicate, membranous wings, whose framework is articulated to the body. Through the aid of muscles which pass from the body to the framework of the wings, these may be moved, and enable the butterfly to fly out into the sunshine.

Man's body has a framework, — the bony skeleton, the parts of which lie deeply buried in the muscles. Without this framework man could not stand erect. The skeleton of man is very much like the skeleton of other vertebrate animals. All vertebrate animals possess *a vertebral column, which is called the axis of the body.*

When the dog or cat is standing on all fours, his vertebral column is horizontal, and his four legs pass downward to the ground as supports. *The four legs of the dog or cat,* together with the large flat bones which fasten them to the vertebral column, are called the appendages of the body axis, or *the appendicular system.* The axis of the body comprises not only the vertebral column, but the skull, as well as the ribs and sternum. The axis, or vertebral column, of the cat or dog is extended backward beyond the body, the bones getting smaller and smaller clear to the tip of the tail. In the case of man and of the higher apes, the axis, or vertebral column, does not extend be-

yond the body, but the last few bones of the vertebral column are grown together into what appears, at first, to be one large, strong bone, called the sacrum, beyond which

is a little bone called the coccyx. Figure 62 gives a side view of the vertebral column, and shows the curved sacrum at the bottom, composed of five vertebræ joined together. At the end of the sacrum there is the little coccyx of four buttonlike bones, usually grown together.

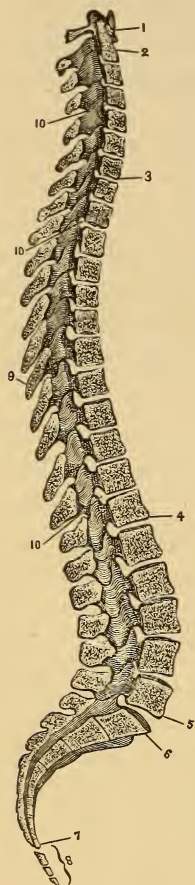


FIG. 62.—Spinal column as it would look if split through the middle from before backwards. Note the names of the different portions and the number of bones or vertebræ in each. 1 to 2, cervical vertebræ; 3 to 4, dorsal vertebræ; 4 to 5, lumbar vertebræ; 5 to 8, sacrum and coccyx.

PROBLEMS

1. To what part of your body does the paw of a cat correspond?

2. Find upon a cat's body the part which corresponds to your elbow.

3. Find the part which corresponds to your knee.

4. Find the part which corresponds to your heel.

5. Find upon a horse's body the part which corresponds to your elbow.

6. To what part of your body does what we call the horse's knee correspond?

7. To what part of your body does the horse's hoof correspond?

8. To what part of the horse's body does your heel correspond?

9. Observe a dressed chicken, and find upon the chicken the part which corresponds to your knee; the part which corresponds to your heel.

10. Find the part which corresponds to your elbow; to your wrist; to your fingers.

1. THE HUMAN SKELETON

I. HOW THE BONES ARE GROUPED

FIGURE 63 gives a front view of the human skeleton. Notice that the first, or upper, joint of the arms has one bone, the *humerus*; and that the corresponding joint of the legs has one bone, the *femur*. Notice, further, that the second joint of the arm corresponds to the second joint of the leg in having two bones. The third joint, or third portion of the anterior limb, comprises the wrist and five digits; while in the leg, the corresponding portion comprises the ankle and five digits. Notice that the arms are held in place by two large flat bones back of the ribs, called the *shoulder blades*, and that the shoulder joint is braced in front by the *collar bones*, which pass from the shoulder blade to the *sternum*. The humerus is joined to the scapula with a *ball and socket joint*, the ball on the end of the humerus fitting into a spherical socket in the shoulder blade. In a similar way, the legs are attached to the axial skeleton through two large, flat, irregular bones called the *innominate bones*. The innominate bones are firmly joined to the *sacrum* behind, and firmly united together in front. This makes a strong basinlike foundation for the whole body, called the *pelvis*. The leg bones are joined to the pelvis by a ball and socket joint; the other joints of the limbs are *hinge joints*.

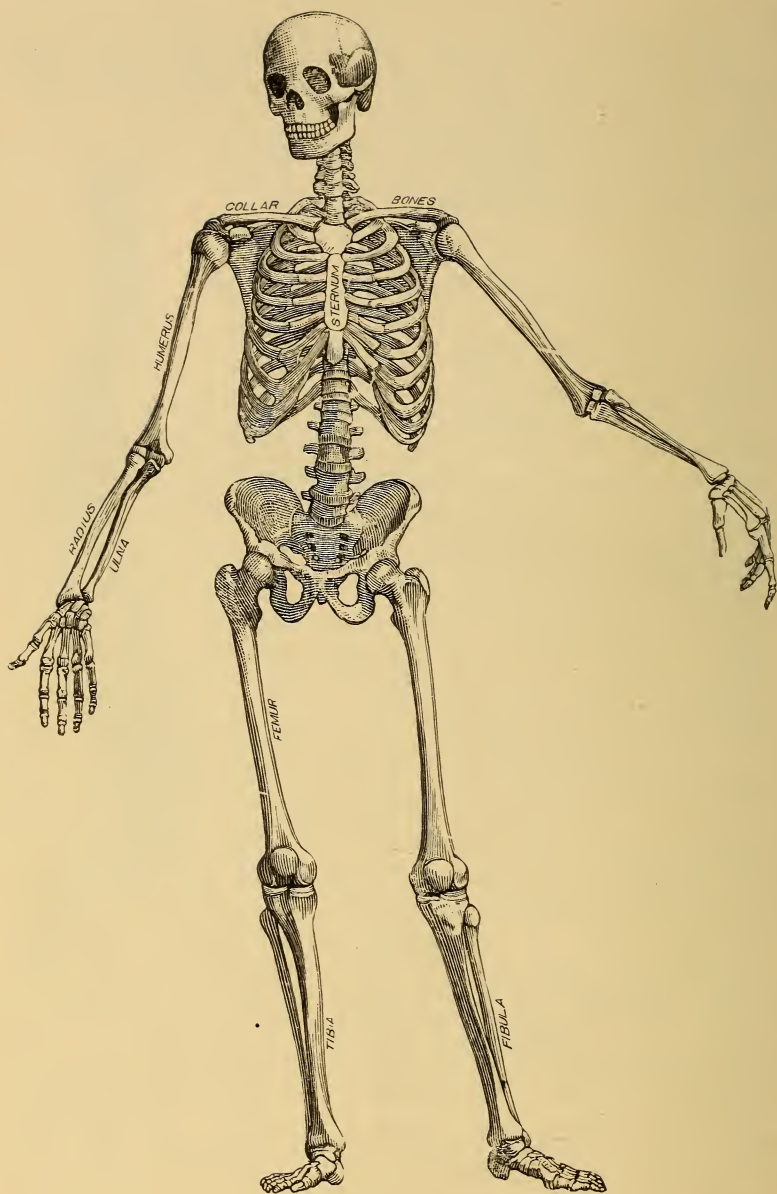


FIG. 63. — The skeleton.

Count up the bones of the skeleton, and see how many you can find. Not counting the teeth and the six little ear bones, the skeleton is composed of two hundred bones. Turning again to Figure 62, notice that the spinal column shown there was sawed through the middle. This shows the canal which passes up through the spinal column, and within which the spinal cord lies. The cord is thus thoroughly protected from harmful pressure or injury. Similarly the brain is always thoroughly protected within the bony cranium which rests upon the top of the spinal column.

In Figure 62 there seems to be space between the vertebræ. These spaces are filled in the living body with a firm, *elastic cartilage*, which gives sufficient opportunity for the bending of the spine, and serves a most important purpose as a series of cushions, which protect the brain from the jarring it would otherwise suffer when one walked or jumped on hard ground.

II. HOW THE BONES ARE MADE

Figure 64 shows the femur as it appears when sawed in two, lengthwise. Notice that the two ends of the bone are larger than the *shaft*, and that they seem to be made differently inside. At the two ends of the bone we find what is called *cancellous tissue*. It is made up of little, thin, bony plates so joined together as to make a very great number of little compartments with thin, bony walls. The little spaces within these bony cells are filled with blood vessels and a tissue which is something like gland tissue. This portion of the bones and similar tissue wherever found in the body, especially within the ribs and in the heads of the long bones, is called *red marrow*

and is the place where red blood corpuscles are formed. *The shaft* of the bone is occupied by a very few blood vessels, all the rest of the space being filled with a deposit of fat, giving the cut bone a yellow appearance. This portion of the bone marrow is called the *yellow marrow*.



FIG. 64. — The right femur, or thigh bone, sawed in two lengthwise. Notice the arrangement of the bony fibers at the upper end, its peculiarity being somewhat exaggerated so as to make it more plain. [Tracy.]

In infancy the bones are very limber and may be easily bent, because they are composed mostly of cartilage or gristle. As the child advances in age, the bones get stronger and stronger owing to a deposit of lime within the bone tissue. If one takes a chicken bone and soaks it in acid, especially diluted hydrochloric acid, he will find that the bone will gradually get softer and softer until it is limber enough to tie into a knot. This change in the bone is due to the mineral matter of the bone being dissolved out.

On the other hand, if one puts a bone into a fire and burns it until it is white, thus burning out all of the animal matter, he will find when he takes it out of the fire that it is brittle and can be crushed in the fingers. These two experiments teach us that a bone gets its stiffness and hardness from the mineral matter and its toughness and flexibility from the animal matter which it contains.

III. HYGIENE OF THE BONES

From what has been said above it is evident that the bones of growing children need mineral matter, and it is further evident that this mineral matter must come through the food. Nature's food for infants (milk) contains the

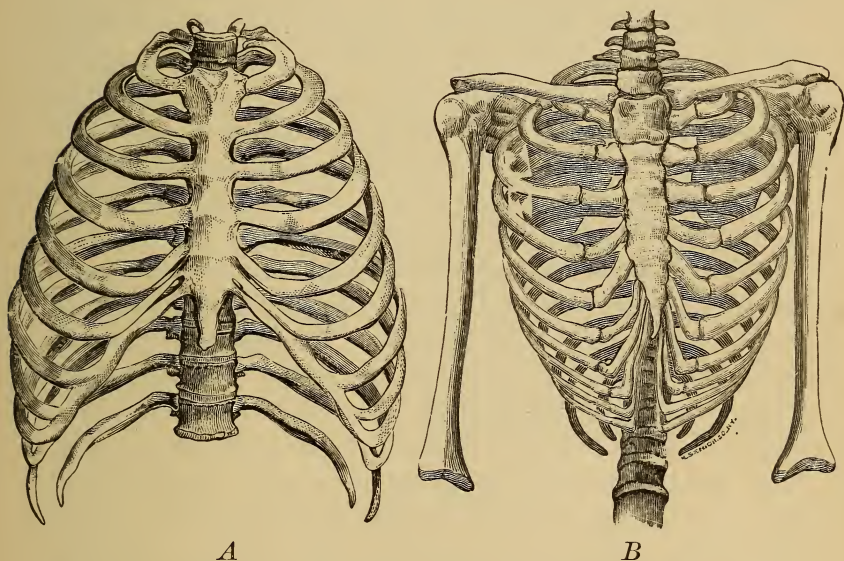


FIG. 65. — *A* represents the normal appearance of the ribs. *B* represents part of a photograph of the skeleton of a young woman of twenty-three years, showing the distortion of the ribs produced by tight lacing. [Tracy.]

mineral matter in sufficient quantity and in proper proportions. After the young child stops making milk its only diet, its food must be chosen with some care in order to provide it with plenty of bone-making material. The cereal foods and the vegetables are the best for this purpose.

The bones of young people and children are very easily

distorted or bent out of their proper shape because they have not yet become stiff and hard through the mineral matter, so it is important that little children in schools or at home should not sit on high seats where the weight of the lower legs and feet hangs from the end of the femur, which rests upon the edge of the seat. Such treatment of the femur would bend it out of its natural shape.

Children and young people should take great care to hold their bodies erect when sitting, standing, walking, or riding. This requires some effort and attention, but if it is done faithfully, one not only gets a habit of erect carriage, but one's bones and muscles later naturally assume these positions, thus giving a person a much more dignified and stately bearing than would otherwise be possible. Figure 65 should be a striking object lesson for those who are inclined to wear clothing too tight to give perfectly free movements for the thorax. In the figure at the right, the vital organs, such as the lungs, heart, stomach, liver, spleen, and pancreas, are all crowded into much narrower space than they are intended by Nature to occupy. This hinders them from doing their best work, and as they are the organs which provide for the general nutrition of the whole system and all the vital processes, it must be evident that the health of an individual whose chest is thus permanently deformed will sooner or later be very seriously interfered with.

INDEX

- Absorption of food, 197.
Adam's apple, 168.
Air, changes in lungs, 179; complementary, 173; composition of, 178; impure, 186; reserve, 173; residual, 173; tidal, 172.
Alcohol, effects of, upon blood, 159; blood corpuscles, 191; on digestion, 115; on heart, 159; on liver and kidneys, 210; on muscles, 257; influence of, general, 69; on nervous system, 246; on skin, 219; how formed, 59; not a food, 110; relation to animal heat, 191; relation to lung diseases, 192.
Alimentary canal, 89.
Amœba, one-celled animal, 34.
Apples, acid fruits, 87.
Arteries, 136, 138.
Automatic action, 55.

Barley, a cereal, 81.
Bathing, 217.
Bicuspid teeth, 91.
Bleeding, protection of body against, 131, 143.
Blood, 128; changed in lungs, 180; coagulation of, 131; condition of, 158; freed of carbon dioxide, 182; figured and described, 129; nourishes tissues, 144; oxygenated, 180; gives up oxygen, 146.
Body heat, 184.
Bones, 263, 265, 267.
Brain, 238, 241, 243; education of, 245; influenced by tobacco, 250.
Breathing, chest and abdominal, 174; forced, 172.
Bronchi, 168.

Cæcum (*sē'cum*), 90.
Canine teeth, 91.

Capillaries, 139, 147.
Cardia of stomach, 93.
Cartilage, figure and description, 39.
Cell, described, 30; diagram of, 29; lymph, 30; of plant, 30; plasm, 30; work of, 28.
Cells, review of, 45; of body, 27.
Cereals, defined and described, 81; experiments with, 83.
Chyle, 150.
Circulation, control of, 151; diagram of, 140; review of, 162.
Circulatory system, 42.
Clothing, 218; effect of, on skeleton, 270.
Coagulation of blood, 131.
Colon, 90.
Colony animal, 38; plant, 37.
Complementary air, 173.
Constrictors of blood vessels, 154.
Corn, plants, 12; a cereal, 81; kernels, 11.
Coughing, 175.
Crying, 176.
Cuticle, 213.

Desmids, one-celled water plants, 33.
Diaphragm, 167.
Digestion by gastric juice, 99; hygiene of, 104; by pancreatic juice, 101; by plants, 21; by saliva, 97; review, 103.
Digestive system, 42; figure of, 90, 91; review of, 96; structure of, 89.
Dilators of blood vessels, 154.
Distillation, described, 61.
Domestic Economy, 118.
Drinks, alcoholic, 110; hygiene of, 107; narcotic, 58; nourishing, 110; refreshing, 109; stimulating, 110.
Duodenum (*dū-ō-de'-num*), 89, 95.

- Ear, description of, 228; hygiene of, 230.
 Economy, domestic, 118.
 Eggs, 78.
 Energy of life, generation of, 203.
 Epidermis, 212, 213.
 Esophagus, 89.
 Excretion by kidneys, 207.
 Exercise, 155; and rest, 256.
 Experiments, in plant physiology, 21; in respiration, 189; on cereals, 83; on foods, 80; on vegetables, 86; with gastric juice, 100; with pancreatic juice, 102; with saliva, 98.
 Expiration, 166, 172, 173.
 Eye, description of, 233; hygiene of, 234.

 Ferment, defined, 22.
 Fermentation, 61, 63.
 Fevers, 185.
 Food, how used in body, 196; absorption of, 197.
 Foods, 78; experiments on, 80, 83, 86; review of, 89.
 Fruit, 86; juices and sirups, 109.

 Gastric juice, digestion by, 99.
 Germ of plant, 20.
 Gland, described, 42.

 Habit, 55, 57.
 Hair, 212.
 Harmony of work, nervous system, 46.
 Hearing, sense of, 228.
 Heart, 133, 134, 139.
 Heat of body, 183.
 Hiccoughing, 176.
 Hygiene, defined, 9; of bones, 269; of circulation, 155; of digestion, 104; of ear, 230; of eye, 234; of kidneys, 208; of liver, 208; of muscles, 255; of respiration, 186; of skin, 216.

 Pleum (*il'e-un*), 89.
 Incisor teeth, 91.
 Inspiration, 166, 172.
 Intestines, 89, 95, 96.
 Iodine, test for proteid, 21; test for starch, 21.
 Jejunum (*jē-jū'num*), 89.

 Kidneys, description of, 207, 208.

 Lacteals, 150.
 Larynx, 168.
 Laughing, 176.
 Legumes as food, 84.
 Lemonade, 109.
 Lemons, acid fruits, 87.
 Levers, 253.
 Liver, 90; description of, 200; hygiene of, 208.
 Lung capacity, 174.
 Lungs, 167, 169.
 Lymph and lymphatics, 147, 148.

 Massage, 156.
 Meat, as food, 87.
 Menus, typical, plain, 88; typical, with price, 124.
 Milk, 78.
 Molar teeth, 91.
 Muscles, 251, 252; experiments, 255; hygiene of, 255.

 Narcotic drinks, general effect of, 65.
 Narcotics, 58; effect of on respiration, 191; review of, 74.
 Nerve, cells, 238, 239; centers, 240; trunks, 240.
 Nervous system, 46, 48, 50, 57, 237; hygiene of, 245; influenced by alcohol, 246; review, 250.
 Nucleolus of cell, 30.
 Nutrition, defined, 76.

 Oats, a cereal, 81.
 Opium, 72.
 Oranges, acid fruits, 87.
 Organs, defined and described, 40; of body, 27; of plant, 17; systems of, 42, 43.
 Oxidation, defined, 15.

 Pancreas (*păn'krē-ās*), 90, 95.
 Pancreatic juice, digestion by, 101.
 Papillæ, of skin, 212; tactile, 220; vascular, 220.
 Parotids (*pā-rōt'ids*), 90.
 Pharynx, 168.
 Physiology, defined, 9, 10; general, 11; special, begins, 75.

- Plant, needs of, 11; parts of, 16; physiology, 9, 11.
 Plants, relation of, to animals, 26.
 Plumule of plant, 20.
 Problems in domestic economy, 123, 125; in respiration, 190; on skeleton, 264.
 Proteid, iodine test for, 21.
 Protococcus, green dust plant, 33.
 Protoplasm of plant, 17.
 Pulse, 143.
 Pylorus of stomach, 93.
- Radicle of plant, 20.
 Rectum, 90.
 Reflex action, 52.
 Residual air, 173.
 Respiration, defined, 164, 165; external, 166; hygiene of, 186; internal, 166; organs of, 166, 167; movements of, 170; review, 193.
 Respiratory system, 42.
 Rest and exercise, 256; time for, 157.
 Rice, a cereal, 81.
 Rye, a cereal, 81.
- Saliva, digestion by, 97.
 Salivary glands, 90.
 Seeing, sense of, 230.
 Sensation, function of skin, 216.
 Sensations, described, 54.
 Sense, of hearing, 228; of position, 222; of seeing, 230; of smell, 226; of taste, 225; of temperature, 221; of touch, 220.
 Senses, general and special, 220; review of special, 236.
 Sighing, 176.
 Skeleton, 263, 266; affected by tight clothing, 270; problems on, 264.
 Skin, description of, 212; hygiene of, 216; organ of sensation, 219; review of, 223.
 Smell, sense of, 226.
 Sneezing, 176.
 Sobbing, 176.
 Soda water, 109.
 Speech, 177.
- Spinal cord, 241, 242.
 Spirits, ardent, 62.
 Starch, iodine test for, 21.
 Stentor, one-celled animal, 36.
 Stomach, 89, 90, 93, 94.
 Sublinguals (*süb-līn'gwäls*), 90.
 Submaxillaries (*süb-mäx'il-lā-ries*), 90.
 Sweat glands, 212.
 Sympathetic nervous system, 51.
 System, circulatory, 42; digestive, 42; respiratory, 42.
- Taste, sense of, 225.
 Teeth, 91, 92.
 Temperature, sense of, 221.
 Tidal air, 172.
 Tissue, defined, 39.
 Tissues, active, 16; of body, 27; review of, 45; supporting, 16.
 Tobacco, 71; effects of, on heart, 161; on brain work, 250; influence of, on respiration, 193.
 Touch, sense of, 220.
 Trachea, 167.
- Valves of veins, 139.
 Vegetables, as food, 84; experiments with, 86.
 Veins, 139.
 Vena cava, 140.
 Ventilation, 187.
 Vertebral column, 263, 264.
 Villi of intestine, 95.
 Villus, organ of absorption, 199.
 Vocal cords, 168.
 Voice, 175, 176.
 Voluntary action, 52.
 Vorticella, one-celled animal, 36.
- Waste matter, how thrown out of body, 206.
 Water, as drink, 107.
 Wheat, a cereal, 81.
 Windpipe, 167.
- Yawning, 176.
 Yeast plant, described, 59.

Text-Books in Physical Training

BLAIKIE'S SOUND BODIES FOR OUR BOYS AND GIRLS

By WILLIAM BLAIKIE, author of "How to Get Strong and How to Stay So." Cloth, 16mo. 40 cents

A manual of simple, practical exercises for the training and development of the body so as to leave no muscle undeveloped. Numerous illustrations are given to make the directions for the various exercises clear and practical. The exercises are free from risk and can be easily learned. They can be practiced in the schoolroom in the brief intervals between the recitations under the eye and direction of the teacher without any loss of time. While the pupils are making progress in their studies they are at the same time building and strengthening their bodies and by so doing secure both bodily vigor and sound health.

MORRIS'S PHYSICAL EDUCATION

By R. ANNA MORRIS. Cloth, 8vo \$1.00

A system of exercises including the Delsartean principles of execution and expression, for use in schools. Each exercise and drill prescribed can be practiced in any school, and the few pieces of apparatus suggested are simple and inexpensive. Part I describes general positions and drills, and furnishes graded instruction for the development for each part of the body. Part II treats of the subject of expression as applied to reading, articulation, and declamation. Musical selections are given to accompany the physical exercises, and appropriate illustrations are added to indicate the movements and positions described.

SMART'S MANUAL OF SCHOOL GYMNASTICS

By JAMES H. SMART. Revised and Enlarged 30 cents

Consisting of free gymnastics, dumb-bell exercises, and aesthetic exhibition exercises, so planned as to develop every part of the body. Movements are provided for standing positions, sitting positions, breathing and vocal exercises, dumb-bell exercises, military movements, and exhibition figures. The book is fully illustrated, and includes a number of musical selections to accompany the gymnastic exercises.

Copies of any of the above books will be sent, prepaid, to any address on receipt of the price by the Publishers:

American Book Company

New York

Cincinnati

Chicago

STORER AND LINDSAY'S
Elementary Manual of Chemistry

By F. H. STORER, S.B., A.M., and W. B. LINDSAY, A.B., B.S.

Cloth, 12mo, 453 pages. Illustrated. Price, \$1.20

This work is the lineal descendant of the "Manual of Inorganic Chemistry" of Eliot and Storer, and the "Elementary Manual of Chemistry" of Eliot, Storer and Nichols. It is in fact the last named book thoroughly revised, rewritten and enlarged to represent the present condition of chemical knowledge and to meet the demands of American teachers for a class book on Chemistry, at once scientific in statement and clear in method.

The purpose of the book is to facilitate the study and teaching of Chemistry by the experimental and inductive method. It presents the leading facts and theories of the science in such simple and concise manner that they can be readily understood and applied by the student. The book is equally valuable in the classroom and the laboratory. The instructor will find in it the essentials of chemical science developed in easy and appropriate sequence, its facts and generalizations expressed accurately and scientifically as well as clearly, forcibly and elegantly.

"It is safe to say that no text-book has exerted so wide an influence on the study of chemistry in this country as this work, originally written by Eliot and Storer. Its distinguished authors were leaders in teaching Chemistry as a means of mental training in general education, and in organizing and perfecting a system of instructing students in large classes by the experimental method. As revised and improved by Professor Nichols, it continued to give the highest satisfaction in our best schools and colleges. After the death of Professor Nichols, when it became

necessary to revise the work again, Professor Lindsay, of Dickinson College, was selected to assist Dr. Storer in the work. The present edition has been entirely rewritten by them, following throughout the same plan and arrangement of the previous editions, which have been so highly approved by a generation of scholars and teachers.

"If a book, like an individual, has a history, certainly the record of this one, covering a period of nearly thirty years, is of the highest and most honorable character."
—*From The American Journal of Science.*

Copies of this book will be sent prepaid to any address, on receipt of the price, by the Publishers:

American Book Company

New York

Cincinnati

Chicago

Burnet's Zoölogy

FOR

HIGH SCHOOLS AND ACADEMIES

BY

MARGARETTA BURNET

Teacher of Zoölogy, Woodward High School, Cincinnati, O.

Cloth, 12mo, 216 pages. Illustrated. Price, 75 cents

This new text-book on Zoölogy is intended for classes in High Schools, Academies, and other Secondary Schools. While sufficiently elementary for beginners in the study it is full and comprehensive enough for students pursuing a regular course in the Natural Sciences. It has been prepared by a practical teacher, and is the direct result of school-room experience, field observation and laboratory practice.

The design of the book is to give a good general knowledge of the subject of Zoölogy, to cultivate an interest in nature study, and to encourage the pupil to observe and to compare for himself and then to arrange and classify his knowledge. Only typical or principal forms are described, and in their description only such technical terms are used as are necessary, and these are carefully defined.

Each subject is fully illustrated, the illustrations being selected and arranged to aid the pupil in understanding the structure of each form.

Copies of Burnet's School Zoölogy will be sent prepaid to any address, on receipt of the price, by the Publishers:

American Book Company

New York

Cincinnati

Chicago

Biology and Zoölogy

DODGE'S INTRODUCTION TO ELEMENTARY PRACTICAL BIOLOGY

A Laboratory Guide for High School and College Students.

By CHARLES WRIGHT DODGE, M.S., Professor of Biology

in the University of Rochester \$1 80

This is a manual for laboratory work rather than a text-book of instruction. It is intended to develop in the student the power of independent investigation and to teach him to observe correctly, to draw proper conclusions from the facts observed, to express in writing or by means of drawings the results obtained. The work consists essentially of a series of questions and experiments on the structure and physiology of common animals and plants typical of their kind—questions which can be answered only by actual investigation or by experiment. Directions are given for the collection of specimens, for their preservation, and for preparing them for examination; also for performing simple physiological experiments.

ORTON'S COMPARATIVE ZOÖLOGY, STRUCTURAL AND SYSTEMATIC

By JAMES ORTON, A.M., Ph.D., late Professor of Natural History in Vassar College. New Edition revised by

CHARLES WRIGHT DODGE, M.S., Professor of Biology in

the University of Rochester \$1.80

This work is designed primarily as a manual of instruction for use in higher schools and colleges. It aims to present clearly the latest established facts and principles of the science. Its distinctive character consists in the treatment of the whole animal kingdom as a unit and in the comparative study of the development and variations of the different species, their organs, functions, etc. The book has been thoroughly revised in the light of the most recent phases of the science, and adapted to the laboratory as well as to the literary method of teaching.

Copies of either of the above books will be sent, prepaid, to any address on receipt of the price.

American Book Company

New York

Cincinnati

Chicago

Gray's Series of Botanies

By the late ASA GRAY, LL.D., of Harvard University

FOR ELEMENTARY AND GRAMMAR SCHOOLS

- Gray's How Plants Grow. With a Popular Flora . . . \$0 80
A simple introduction to the study of Botany.
Gray's How Plants Behave. A Botany for Young People 54
A primary book showing how plants move, climb, act, etc.

FOR SECONDARY SCHOOLS

- Gray's Lessons in Botany. Revised edition 94
Gray's Field, Forest, and Garden Botany. New edition,
containing Flora only 1.44
Gray's School and Field Book of Botany. Comprising the
"Lessons" and "Field, Forest, and Garden Botany," 1.80
A complete book for school use.

FOR COLLEGES AND ADVANCED STUDENTS

- Gray's Manual of Botany. Revised, containing Flora only.
For the Northern United States, east of the Mississippi, 1.62
The Same. Tourist's edition. Thin paper, flexible leather, 2.00
Gray's Lessons and Manual of Botany. One volume. Revised,
comprising the "Lessons in Botany" and the "Manual," 2.16
Gray's Botanical Text-Book
I. Gray's Structural Botany 2 00
II. Goodale's Physiological Botany 2.00

FOR WESTERN STUDENTS

- Coulter's Manual of the Botany of the Rocky Mountains . . 1.62
Gray and Coulter's Text-Book of Western Botany. Com-
prising Gray's "Lessons" and Coulter's "Manual of
the Rocky Mountains" 2.16

*Copies of any of the above books will be sent, prepaid, to any address
on receipt of the price by the Publishers:*

American Book Company

NEW YORK

• CINCINNATI •

CHICAGO

NOV 6 1900

LIBRARY OF CONGRESS



0 005 526 647 5

